

AGRICULTURE CANADA
CODE 86/02/21

NO.

LIBRARY/BIBLIOTHEQUE OTTAWA K1A 0C5

FERTILIZERS FOR FIELD CROPS

THEIR NATURE, FUNCTIONS AND APPLICATION

WITH

RESULTS FROM RECENT EXPERIMENTS
IN CANADA

BY

FRANK T. SHUTT, M.A., D.Sc.;
Dominion Chemist

AND

B. LESLIE EMSLIE, C.D.A., F.C.S.;
Soil Fertility Specialist

DIVISION OF CHEMISTRY

DOMINION EXPERIMENTAL FARMS

DOMINION OF CANADA
DEPARTMENT OF AGRICULTURE
BULLETIN NO. 8—NEW SERIES

Printed by authority of the Hon. W. R. Motherwell, Minister of Agriculture, Ottawa

630.4
C212
B 8
n.s.
1922
c. 3

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1922

DOMINION EXPERIMENTAL FARMS BRANCH

PERSONNEL

DIRECTOR, E. S. ARCHIBALD, B.A., B.S.A.

Dominion Field Husbandman.....	E. S. Hopkins, B.S.A., M.S.
Dominion Chemist.....	F. T. Shutt, M.A., D.Sc.
Dominion Horticulturist.....	W. T. Macoun.
Dominion Cerealist.....	C. E. Saunders, B.A., Ph.D
Dominion Botanist.....	H. T. Güssow.
Dominion Animal Husbandman.....	G. B. Rothwell, B.S.A.
Dominion Forage Crop Specialist.....	
Dominion Poultry Husbandman.....	F. C. Elford.
Dominion Tobacco Husbandman.....	F. Charlan, B.Sc.
Dominion Apiarist.....	C. B. Gooderham, B.S.A.
Chief Officer, Extension and Publicity.....	F. C. Nunnick, B.S.A.
Chief Supervisor of Illustration Stations.....	John Fixter.
Economic Fibre Specialist.....	R. J. Hutchinson.

ALBERTA

Superintendent, Experimental Station, Lacombe, Alta.....	F. H. Reed, B.S.A.
Superintendent, Experimental Station, Lethbridge, Alta.....	W. H. Fairfield, M.S.
Superintendent, Experimental Sub-station, Beaverlodge, Alta.....	W. D. Albright.
Superintendent, Experimental Sub-station, Fort Vermilion, Alta.....	Robt. Jones.

BRITISH COLUMBIA

Superintendent, Experimental Farm, Agassiz, B.C.....	W. H. Hicks, B.S.A.
Superintendent, Experimental Station, Summerland, B.C.....	R. H. Helmer.
Superintendent, Experimental Station, Invermere, B.C.....	R. G. Newton, B.S.A.
Superintendent, Experimental Station, Sidney, B.C.....	E. M. Straight, B.S.A.

MANITOBA

Superintendent, Experimental Farm, Brandon, Man.....	W. C. McKillican, B.S.A.
Superintendent, Experimental Station, Morden, Man.....	W. R. Leslie, B.S.A.

SASKATCHEWAN

Superintendent, Experimental Farm, Indian Head, Sask.....	N. D. McKenzie, B.S.A.
Superintendent, Experimental Station, Rosthern, Sask.....	W. A. Munro, B.S.A.
Superintendent, Experimental Station, Scott, Sask.....	M. J. Tinline, B.S.A.
Superintendent, Experimental Station, Swift Current, Sask.....	J. G. Taggart, B.S.A.

NEW BRUNSWICK

Superintendent, Experimental Station, Fredericton, N.B.....	C. F. Bailey, B.S.A.
---	----------------------

NOVA SCOTIA

Superintendent, Experimental Farm, Nappan, N.S.....	W. W. Baird, B.S.A.
Superintendent, Experimental Station, Kentville, N.S.....	W. S. Blair.

PRINCE EDWARD ISLAND

Superintendent, Experimental Station, Charlottetown, P.E.I.....	J. A. Clark, B.S.A.
---	---------------------

ONTARIO

Central Experimental Farm, Ottawa, Ont.....	
Superintendent, Experimental Station, Kapuskasing, Ont.....	S. Ballantyne.
Superintendent, Tobacco Experimental Station, Harrow, Ont.....	D. D. Digges, B.S.A., M.S.A.

QUEBEC

Superintendent, Experimental Station, Cap Rouge, Que.....	G. A. Langer.
Superintendent, Experimental Station, Lennoxville, Que.....	J. A. McClary, B.S.A.
Superintendent, Experimental Station, Ste. Anne de la Pocatière, Que.....	J. A. Ste. Marie, B.S.A.
Superintendent, Experimental Station, La Ferme, Que.....	P. Fortier.
Superintendent, Tobacco Experimental Station, Farnham, Que.....	J. E. Montreuil, B.S.A.

FERTILIZERS FOR FIELD CROPS

THEIR NATURE, FUNCTIONS AND APPLICATION

WITH

RESULTS FROM RECENT EXPERIMENTS
IN CANADA

BY

FRANK T. SHUTT, M.A., D.Sc.,
Dominion Chemist

AND

B. LESLIE EMSLIE, C.D.A., F.C.S.,
Soil Fertility Specialist

DIVISION OF CHEMISTRY

DOMINION EXPERIMENTAL FARMS

DOMINION OF CANADA DEPARTMENT OF AGRICULTURE BULLETIN No. 8—NEW SERIES
--

Printed by authority of the Hon. W. R. Motherwell, Minister of Agriculture, Ottawa

OTTAWA
F. A. ACLAND
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1922

TABLE OF CONTENTS

	PAGE
Introduction.....	7

CHAPTER I

NITROGEN

Nitrogen in the Soil Humus.....	8
“ and Nitrification.....	8
“ Organic, Ammoniacal and Nitrate.....	8
“ Losses of, from soil.....	8
“ Importance of Nitrate, in Spring.....	8
“ Relative Value of, in various forms.....	11
“ Influence of, on Turnips at Charlottetown.....	13
“ “ “ Potatoes and Roots at eight Stations.....	12
“ “ “ Mangels at Agassiz.....	11
“ “ “ Oats.....	9
“ “ “ various crops in Kentville rotations.....	15

CHAPTER II

PHOSPHORIC ACID

Phosphoric Acid, Influence of, on root development and seed formation.....	17
“ as present in Superphosphate, Basic Slag and Bone.....	18
“ influence of, in promoting crop maturity.....	17
“ relative value of various forms of.....	18
“ Influence of, on cereals and corn at seven Stations.....	17
“ “ “ Mangels at Agassiz.....	20
“ “ “ Potatoes at Kapuskasing.....	21
“ “ “ various crops in Kentville rotations.....	18
“ “ “ “ “ Fredericton rotations.....	20

CHAPTER III

POTASH

Potash, in relation to Carbohydrate formation.....	23
“ as Muriate, Sulphate, Carbonate, etc.....	23
“ Varying the quantity of, in the Fertilizer.....	23
“ Response to, by crops at Agassiz.....	24
“ Influence of, on Turnips at Charlottetown.....	24
“ “ “ Potatoes at Kapuskasing.....	24
“ “ “ various crops in Kentville rotations.....	26

CHAPTER IV

MINERAL AND ORGANIC FERTILIZER MATERIALS

Nitrogen from Organic Sources.....	28
Nitrate of Soda versus Whale Guano at Agassiz.....	28
Nitrates of Soda and of Lime versus Dried Blood at Ottawa.....	29
Nitrogen and Phosphoric Acid—Mineral versus Organic Sources.....	30
“ “ “ furnished wholly or partly by mineral materials.....	31
“ “ “ “ “ organic materials.....	31
Tankage as a Source of Nitrogen and Phosphoric Acid.....	31
Bone Meal compared with Superphosphate at three Stations.....	28

CHAPTER V

MANURE WITH FERTILIZERS AND LIME

	PAGE
Manure, Value of, in Rotation Experiments at Kentville.....	32
“ in Experiments at Agassiz.....	32
Lime as a Supplement to Manure and Fertilizers.....	33
Ground Limestone, Influence of, at Kentville.....	33
“ “ versus Burnt Lime at Cap Rouge.....	34
“ “ “ “ Kapuskasing.....	35
Lime in various forms compared at Kapuskasing.....	35

CHAPTER VI

FARMYARD MANURE AND GREEN MANURING

Manure, Its Nature and Composition.....	37
“ How to avoid losses from.....	38
“ Its Influence in the Soil.....	38
“ “ Chemical Influence.....	38
“ “ Physical “.....	38
“ “ Biological “.....	39
“ Litter as influencing Quality of.....	39
“ Its Application.....	39
“ Losses from, determined by investigations.....	39
Green Manures.....	40
“ “ as Clover, Vetch, Buckwheat, Rye, Rape.....	40
“ “ furnish humus to the soil.....	40
Humus, Importance of.....	41

CHAPTER VII

FERTILIZER MATERIALS, THEIR ORIGIN, NATURE AND USES

Essential Elements of Fertility (Nitrogen, Phosphoric Acid and Potash).....	42
“ “ Their Chief Functions.....	43
Soil Fertility, Exhaustion of, by cropping.....	42
“ “ as measured by Nitrogen Content.....	42
Plant Food Requirements, Theories respecting.....	43
“ “ removed by principal field crops.....	44
Fertilizers, Their Place in Agriculture.....	44
“ “ Primary Function.....	44
“ “ Composition (Table).....	50
“ Origin and Sources of.....	45
“ Commercial.....	45
“ Act, Dominion.....	45
“ Brand Names of Commercial.....	45
Nitrogenous Fertilizers.....	
(Nitrate of Soda, Sulphate of Ammonia, Dried Blood, Tankage, Cyanamide, Nitrate of Lime).....	46
Phosphatic Fertilizers.....	
(Bones, Rock Phosphate, Superphosphate, Basic Slag, Bone Tankage, etc.).....	47
Potassic Fertilizers.....	
(Muriate of Potash, Sulphate of Potash, Kainit, Wood Ashes, Seaweed, etc.).....	49
European Potash.....	49
American Potash.....	49

CHAPTER VIII

LIME AND OTHER SOIL AMENDMENTS

Lime, Burnt, Slaked.....	51
Limestone, Ground.....	51
Marl.....	51
Liming, The Need for.....	51
Soil Acidity, Test for.....	53
Lime, Chemical, Physical and Biological Influences of.....	52
Lime Compounds, Comparative Values of.....	52
“ “ Application of.....	54
Gypsum or Land Plaster.....	53
Indirect Fertilizers.....	54
(Nitrate of Soda, Common Salt, Gypsum, Lime, etc.).....	

CHAPTER IX

FERTILIZER FORMULAE AND HOME-MIXING

	PAGE
Formulae, Fertilizer	56
“ Interpretation of.....	56
“ As a Guide to the Value of a Fertilizer.....	56
“ Compounding Fertilizers according to.....	56
Unit, The, Interpretation of	56
“ “ as a Factor in Calculating Fertilizer Values.....	56
Fertilizer Mixtures, Preparation of, on the Farm	57
Fertilizers, Methods Employed in the Application of	58
“ The Time of Their Application.....	58

CHAPTER X

FERTILIZER NEEDS OF VARIOUS CROPS

Fertilizer Requirements of Field Crops	59
“ “ as Influenced by the Character of the Soil.....	59
“ “ Seasonal or Climatic Conditions.....	59
“ “ Previous Treatment of the Land.....	59
“ Treatment Suggested for Various Field Crops	60
Grain Crops, Potatoes, Turnips, Mangels, Beets, Corn.....	60
Timothy, Clover, Alfalfa, Flax, Tobacco, Vegetables, Fruit.....	61
Fertilizer Mixtures Containing Organic Materials	63

INTRODUCTION

This bulletin has been prepared chiefly in response to the ever increasing interest shown by farmers for general practical information respecting fertilizers for field crops. As far as may have been possible it has been made an up-to-date, brief, brief treatise on this subject, discussing the nature and functions of fertilizers and presenting and summarizing new data from our own experimental work with fertilizer materials. These results from investigational work in the Dominion, while confined to selected problems, have indicated a desirable means of important information in regard to fertilizer farming.

In 1915 a bulletin entitled "The Growing of Market Garden Crops with Special Reference to the Use of Fertilizers" was written and since that date several other decisions in relation to the requirements of the fertilizer problems have been issued. These have covered more details. They have received a fairly wide distribution and there is every reason to believe that they have very satisfactorily fulfilled their purpose. They will, therefore, between the need for definite specific information is required in the matter of fertilizers available in general and the conditions under which they are to be successfully obtained and practically used for farm crops. This bulletin is based on all satisfactorily supply the desired information.

The present and scope of the bulletin were suggested largely by the nature of the questions submitted by our readers. Some of the chief questions were: (1) the results from recent field experiments; (2) the functions of the various fertilizers and (3) the value of the various soil tests. The bulletin will also contain: (1) an explanation of the functions and functions of fertilizers in the matter of fertilizers and production of crops; (2) a summary of the results from the field tests of field crops, etc.

The arrangement and nature of the material are suggested with greater simplicity and detail to the Table of Contents which should be referred to by the reader.

FERTILIZERS FOR FIELD CROPS

THEIR NATURE, FUNCTIONS AND APPLICATION

WITH

RESULTS FROM RECENT EXPERIMENTS IN THE DOMINION

BY

FRANK T. SHUTT, M.A., D.Sc.,

Dominion Chemist

AND

B. LESLIE EMSLIE, C.D.A., F.C.S.,

Soil Fertility Specialist

INTRODUCTION

This bulletin has been prepared chiefly in response to the ever-increasing, insistent demand by farmers for precise, practical information respecting fertilizers for field crops. As far as may have been possible it has been made an up-to-date, though brief treatise on this subject, discussing the nature and functions of fertilizers and presenting and interpreting new data from our own experimental work with fertilizer materials. These results from investigational work in the Dominion, while confirming established principles, have indicated as desirable certain important modifications in respect to fertilizer formulæ.

In 1917 a bulletin, entitled "The Manuring of Market Garden Crops with special reference to the use of Fertilizers," was written and since that date several circulars dealing in outline with special phases of the fertilizer problem have been issued. These have proved most useful. They have received a fairly wide distribution and there is every reason to believe that they have very satisfactorily fulfilled their purpose. There still remained however the need for definite, concise information in respect to the nature of fertilizer materials in general and the conditions under which they may be economically selected and profitably used for farm crops. This bulletin, it is hoped, will satisfactorily supply the desired information.

The plan and scope of the bulletin were suggested largely by the nature of the enquiries submitted by our correspondents, and it was deemed advisable to bring under one cover (1) the results from recent field experiments, (2) a discussion of the source, nature, function and value of the various manures, fertilizers and soil amendments, (3) an explanation of the formulæ and factors involved in the valuation of fertilizers and preparation of home-mixtures, and (4) suggestions for the fertilizer treatment of field crops, etc.

The arrangement and nature of the material are indicated with greater precision and detail in the Table of Contents, which should be consulted by the reader.

CHAPTER I

NITROGEN

In all schemes of fertilizing it is generally conceded that of the several elements withdrawn from the soil by the growing crop, as a rule three only must be, from time to time, returned in order that productiveness may be maintained or increased. These three are nitrogen, phosphoric acid and potash and are commonly known as the essential elements of fertility.

Of the three so-called essential elements of plant food, nitrogen proves most frequently the limiting factor. The supply of available nitrogen in the soil determines largely the extent of plant growth and the ability of the crop to avail itself of the other elements of plant food present. Nitrogen is found in greatest concentration in the plant tissues of the most actively growing parts.

Precedence, therefore, in this treatise will be given the results from investigations revealing more particularly the influence of nitrogen.

NITROGEN IN THE SOIL

A knowledge of the conditions governing the supply of available nitrogen in the soil and its absorption by plants is useful as a guide to fertilizer treatment.

The natural storehouse of nitrogen in the soil is humus, the partially decomposed organic matter derived chiefly from crop residues and farm manure.

Soils deficient in humus are naturally unproductive, both from lack of nitrogen and of these desirable physical qualities which humus imparts.

NITRIFICATION AND AVAILABLE NITROGEN

Until it has undergone conversion into the nitrate form, the nitrogen present in the organic matter of soils, is unavailable to plants. The process of nitrification is performed by certain soil micro-organisms which attack, break down and change the organic matter to other forms.

In each of the various steps of the process in respect to nitrogen—e.g., from organic nitrogen to ammonia, from ammonia to nitrite and from nitrite to nitrate nitrogen—a special class of bacteria is engaged. These bacteria require for their development and activities, in addition to their food material, favourable degrees of moisture, air and heat.

In early spring, before the soil temperature has been raised to the degree necessary for nitrification, nitrates, even in some of the most fertile soils, will be lacking, and this fact explains the usually remarkable response of certain crops to early spring applications of nitrate of soda, a fertilizer which, as its name implies, contains its nitrogen in the immediately available nitrate form.

NITRATES LEACHED FROM THE SOIL

In order that the reader may comprehend more fully the subsequent discussion, it should be remarked that nitrates formed in the soil in excess of crop requirements will in the late summer and autumn, after the removal of the crop, tend to be leached to the lower sub-soil layers and removed largely in the drainage water. The downward trend of the soil moisture sets in with the colder weather in the fall, with the decline in the degree of evaporation which had hitherto promoted the upward capillary flow of the moisture. This leaching and removal of nitrates in the soil drainage is most pronounced in light soils with pervious subsoils in regions with heavy precipitation and especially from bare soils.

INFLUENCE OF NITRATE OF SODA ON THE OAT CROP AT AGASSIZ, B.C.

As a very notable illustration of the response of crops to nitrate nitrogen, we present here data furnished by Experiment E at Agassiz, B.C. This experiment was commenced in the year 1918 and continued throughout a three-year crop rotation consisting of mangels, oats and hay. The plan embraced 65 plots, 60 of which were treated with various quantities and combinations of fertilizers with light and heavier dressings of manure.

The soil of the area is a sandy loam overlying a gravelly subsoil.

By reason of the leaching of soluble nitrogen (nitrates) from the soil during the period—chiefly in the fall—when it is unoccupied by a growing crop, the influence of nitrate of soda, applied in the first year, could not be expected to extend, in any appreciable degree, to the grain crop of the second year. Recognition of this fact led to the provision in the scheme for repeating the application of nitrate of soda on certain plots at the time of seeding the oats, in the spring of 1919. Four series of three plots each—in all 12 plots—which had received (in 1918) nitrate of soda at the respective rates of 266, 200 and 133 pounds per acre, were divided and one-half of each plot was treated (in 1919) with the same quantity of nitrate as it had received in the former year.

Conditions at Agassiz in the spring of 1919 proved ideal for demonstrating the influence of nitrate of soda. The spring was wet and cold and the succeeding summer dry and hot. Consequently all plots, except those on which the application of nitrate had been repeated, produced abnormally low yields both of grain and straw.

The oats were seeded on April 30—the nitrate being applied to the twelve plots on the same day—and harvested on July 5—a rather short season of growth.

Table No. I shows the yields of grain and straw produced on each plot and the increased yields from the half plots receiving nitrate in 1919.

The lower section of the table presents the averages of the four series. In the fourth series it will be noted that the plots number from 12 B to 13 AA instead of from 12 A to 12 CC. This is due to an error which occurred in the field at the time the nitrate was applied, plot 12 B having been mistaken for 12 A. The results are, however, unaffected thereby.

DISCUSSION OF THE DATA PRESENTED IN TABLE 1

By referring to the first column, it will be seen that the half-plots receiving nitrate in the second year are designated AA, BB, CC, to distinguish them from the corresponding half plots receiving no nitrate in the second year. Prior to the commencement of the rotation, all plots received, in 1918, manure at the rate of 10 tons per acre.

Columns 2, 3, 4, show the fertilizer treatment of the plots in the first year (1918) and column 5 shows the nitrate of soda application made to the AA, BB, CC plots of each series in the second year (1919).

The yields are recorded in columns 6 and 7 and the increases, due to nitrate, in columns 8 and 9.

These figures speak for themselves in no uncertain manner, and indicate clearly and irrefutably that a lack of available nitrogen (nitrates) was responsible for the small yields in 1919 of the plots which received no nitrate of soda that season. In

TABLE I—RESULTS FROM THE USE OF NITRATE OF SODA ON THE OAT CROP OF 1919

Plot	Fertilizer Treatment of the Plots in the year 1918			Nitrate of Soda applied April 30, 1919	Yields per acre		Increase per acre	
	Nitrate of Soda (in pounds per acre)	Super-phosphate (in pounds per acre)	Muriate of Potash (in pounds per acre)		Grain	Straw	Grain	Straw
					Bush.	lbs.	Bush.	lbs.
2 A.....	266	1,000	320	.....	22.4	1,720		
2 AA.....	266	1,000	320	266	51.8	4,000	29.4	2,280
2 B.....	200	750	240	.....	28.2	1,360		
2 BB.....	200	750	240	200	56.5	3,760	28.3	2,400
2 C.....	133	500	160	.....	22.4	1,320		
2 CC.....	133	500	160	133	41.2	3,400	18.8	2,080
4 A.....	266	500	320	.....	25.9	1,760		
4 AA.....	266	500	320	266	64.7	4,360	38.8	2,600
4 B.....	200	375	240	.....	23.5	1,360		
4 BB.....	200	375	240	200	56.5	3,600	33.0	2,240
4 C.....	133	250	160	.....	16.5	1,360		
4 CC.....	133	250	160	133	33.0	3,040	16.5	1,680
6 A.....	266	1,000	160	.....	20.0	1,800		
6 AA.....	266	1,000	160	266	72.9	4,240	52.9	2,440
6 B.....	200	750	120	.....	20.0	1,560		
6 BB.....	200	750	120	200	54.1	4,480	34.1	2,920
6 C.....	133	500	80	.....	23.5	1,680		
6 CC.....	133	500	80	133	36.5	3,880	13.0	2,200
12 B.....	200	750	.....	.....	10.6	1,320		
12 BB.....	200	750	.....	266	40.0	4,480	29.4	3,160
12 C.....	133	500	.....	.....	12.9	1,640		
12 CC.....	133	500	.....	200	40.0	4,080	27.1	2,440
13 A.....	533	500	.....	.....	15.3	1,240		
13 AA.....	533	500	.....	133	41.8	3,520	26.5	2,280
Averages—								
4 plots.....				.....	19.7	1,650		
4 plots.....				266	57.3	4,270	37.6	2,620
4 plots.....				.....	21.1	1,480		
4 plots.....				200	51.8	3,980	30.7	2,500
4 plots.....				.....	19.4	1,400		
4 plots.....				133	38.1	3,460	18.7	2,060

nearly every instance the yields have been doubled, and in three, more than trebled, by the nitrate. A point of further significance is noted in the fact that, without a single exception, the increases in yield correspond in direct ratio to the amount of nitrate furnished. Thus, 266 pounds produces the greatest, 200 pounds somewhat less, and 133 pounds the least increase in each series.

Results so consistent and conclusive as these are rare. The nature of the season and of the light, leachy soil combined to emphasize the stimulating influence of the nitrate, which in these particular experiments was very pronounced.

Though, as will be seen, all the plots were fertilized liberally in preparation for the mangel crop of 1918, no favourable influence of the phosphoric acid was noticeable on the oat crop of 1919. That of potash, however, is discernible on comparing the lower yields from Series 12 (no potash) with those from the three other series and which received potash in the initial fertilizing. (See Chapter 3.)

INFLUENCE OF NITRATE ON THE MANGEL CROP AT AGASSIZ

Having noted the importance of an early spring supply of nitrate as illustrated in the oat crop of 1919, we now revert, as it were, to the former year and study the influence of nitrate of soda on the mangel crop of 1918.

Plots which are comparable are brought together in Table 2 which permits the studying of the effect of doubling the quantity of nitrate, the phosphoric acid and potash remaining the same in each group.

TABLE 2.—VARYING THE QUANTITY OF NITRATE OF SODA IN THE FERTILIZER MANGEL CROP, 1918

Plot	Manure	Fertilizer Treatment (in lbs. per acre)			Yield of Mangels per acre	Increase per acre due to doubling the quantity of Nitrate
		Nitrate of Soda	Super- phosphate	Muriate of Potash		
					bush.	bush.
3 A.....	Ten (10) tons per acre throughout	533	500	320	916.8	122.4
4 A.....		266	500	320	794.4	
3 B.....		400	375	240	828.0	172.0
4 B.....		200	375	240	656.0	
3 C.....		266	250	160	755.2	176.8
4 C.....		133	250	160	578.4	
2 C.....		133	500	160	648.8	239.2
10.....		.....	500	160	409.6	

DISCUSSION OF THE DATA PRESENTED IN TABLE 2

Profitable increases in yields were produced by doubling (in the first plot of each pair) the quantity of nitrate of soda in the fertilizer. While plot 3 A gave the highest yield, plot 3 B, because of the lower cost of the fertilizer used, produced the more profitable increase. The results in general, from this investigation, indicate 400 pounds per acre of nitrate of soda to be the maximum amount for profitable application in any one year, under the circumstances.

Plot 10, which received no nitrate in the fertilizer, gave a yield very much lower than that from any other fertilized plot in the whole experiment. The addition of 133 pounds of nitrate of soda increased the yield by nearly 240 bushels per acre.

NITRATE OF SODA VERSUS SULPHATE OF AMMONIA

Nitrate of soda, as noted already, is the only fertilizer on our markets, which contains its nitrogen in the immediately available nitrate form. Consequently, it may be accorded a relatively higher agricultural value than other nitrogenous fertilizers,

the nitrogen of which must first undergo conversion, in the soil, to the nitrate form, in order to become assimilable.

Sulphate of ammonia, on soils plentifully supplied with lime and with certain field crops which make their chief vegetative growth comparatively late in the season may and frequently does give results comparable with those from nitrate of soda.

THE EXPERIMENT AT EIGHT EXPERIMENTAL STATIONS

In the years 1915 and 1916 experiments designed to ascertain the relative values of nitrate of soda and sulphate of ammonia as a nitrogenous fertilizer were undertaken at eight Farms and Stations of the Dominion Experimental Farms System.

In 1915 the investigation was carried out at Charlottetown, P.E.I., Kentville, N.S., Fredericton, N.B., Cap Rouge, Que., and Agassiz, B.C., and in 1916 at Nappan, N.S., Lennoxville, Que., and Sidney, B.C.

At four Stations the experimental crop was *potatoes*, at two, *swede turnips*, at one, *mangels* and at one other, *oats*.

No manure was applied, and, in view of this, the quantity of nitrogen furnished in the fertilizer was inadequate for the production of normal yields of potatoes and root crops.

In addition to a uniform, liberal application of phosphoric acid and potash, one plot received nitrate of soda at the rate of 133 pounds per acre, and one sulphate of ammonia at the rate of 100 pounds per acre, the amount of nitrogen furnished in each case being the same.

TABLE 3.—NITRATE OF SODA VERSUS SULPHATE OF AMMONIA (1915-16)

Station	Nitrogenous Fertilizer	Crop	Yield	Greater Yield from Nitrate plot	Relative Value of Sulphate of Ammonia if Nitrate equal to 100
			Bush.	Bush.	p.c.
Charlottetown, P.E.I.	Nitrate of soda.....	Potatoes....	84.0	13.5	84.0
	Sulphate of ammonia....	"	70.5		
Kentville, N.S.	Nitrate of soda.....	"	141.1	7.7	94.6
	Sulphate of ammonia....	"	133.4		
Fredericton, N.B.	Nitrate of soda.....	"	254.8	5.5	97.8
	Sulphate of ammonia....	"	249.3		
Cap Rouge, Que.	Nitrate of soda.....	"	74.7	21.2	72.0
	Sulphate of ammonia....	"	53.5		
Nappan, N.S.	Nitrate of soda.....	Turnips.....	386.4	91.9	76.2
	Sulphate of ammonia....	"	294.5		
Lennoxville, Que.	Nitrate of soda.....	"	602.7	74.3	87.7
	Sulphate of ammonia....	"	528.4		
Agassiz, B.C.	Nitrate of soda.....	Mangels....	559.6	184.9	67.0
	Sulphate of ammonia....	"	374.7		
Sidney, B.C.	Nitrate of soda.....	Oats.....	77.2	5.4	93.0
	Sulphate of ammonia....	(Grain).....	71.8		

DISCUSSION OF THE DATA PRESENTED IN TABLE 3

It will be noted that in most instances the difference in favour of nitrate of soda was quite marked. The yields, however, are abnormally low, due, doubtless, in a large measure to the fact that, in the absence of manure, the amount of nitrogen in the fertilizer (20 pounds per acre) applied in the form of either nitrate of soda or sulphate of ammonia, was too small to meet the requirements of a full crop.

The results, nevertheless, are convincing and conclusions drawn therefrom have a wide application in view of the diversified nature of the crops under experiment.

Taking the influence of nitrogen in the form of nitrate of soda as being represented by 100, the figure representing the average influence of nitrogen in the form of sulphate of ammonia in these experiments, is found to be 84.

SOURCES OF NITROGEN EXPERIMENT AT CHARLOTTETOWN

In this experiment, carried out at the Experimental Station of Charlottetown, P.E.I., four nitrogenous fertilizers—nitrate of soda (15 per cent) sulphate of ammonia (20 per cent) cyanamide (14 per cent) and Nitrapo (15 per cent)—were compared. (The percentage figures represent the nitrogen present in each of these materials).

The soil is a medium loam of moderate fertility but unmanured for several years, and the experimental crop was turnips.

Cyanamide is the product of an electrical process whereby the nitrogen of the atmosphere combines with lime and carbon. One of the leading cyanamide factories is situated at Niagara Falls, Ont., but the product finds its chief market in the United States, where it is used to a considerable extent as a partial source of nitrogen in commercial fertilizer mixtures.

Cyanamide when first applied to the soil forms, presumably, a small quantity of an intermediate compound dicyanodiamide, which is poisonous to germinating seeds and young plants. For this reason it cannot be applied with impunity later than two weeks before seeding or planting. The nitrogen of cyanamide becomes available in the soil by its conversion first to ammonia and then to the nitrate form.

"Nitrapo" is a by-product of the Chilean Nitrate Industry and consists of a mixture of nitrate of soda and nitrate of potash, so combines the qualities of the former with those of potash in its most readily available form. Since Nitrapo contains 15 per cent of nitrogen and 15 per cent of potash, 100 pounds of this material is equivalent to 100 pounds of nitrate of soda plus 30 pounds of muriate of potash. While the annual production of Nitrapo is not of a volume sufficient to warrant its recognition as a staple article of commerce, its concentrated and soluble form commends it highly as a nitro-potassic fertilizer. Its value as a source of potash will be discussed in Chapter 3.

Table 4 shows that each nitrogenous fertilizer was applied singly (plots 2, 3, 10) also with superphosphate (6, 8) or with superphosphate and muriate of potash (7, 9). The small quantity of cyanamide available for this experiment did not permit of its inclusion in a mixture.

In whatever form, the amount of nitrogen furnished is the same in each instance, viz., 30 pounds per acre. Phosphoric acid, where furnished, is at the rate of 48 pounds, and potash at the rate of 30 pounds per acre.

TABLE 4.—SOURCES OF NITROGEN—CHARLOTTETOWN, 1921

Plot No.	Fertilizers applied	Rate per acre	Elements furnished	Yield of Turnips per acre (average of duplicate plots)
		lbs.		bush.
4	Check.....			646.0
2	Nitrate of soda.....	200	Nitrogen.....	790.8
3	Sulphate of ammonia.....	150	"	492.4
10	Cyanamide.....	225	"	410.4
6	Nitrate of soda..... Superphosphate.....	200 300	Nitrogen and phosphoric acid.....	757.2
8	Sulphate of ammonia..... Superphosphate.....	150 300	"	588.4
7	Nitrate of soda..... Superphosphate..... Muriate of potash.....	200 300 60	Nitrogen, phosphoric acid and potash.....	876.8
9	Sulphate of ammonia..... Superphosphate..... Muriate of potash.....	150 300 60	"	813.6
5	Nitrapo..... Superphosphate.....	200 300	"	899.6
1	Nitrapo.....	200	Nitrogen and potash.....	805.6

DISCUSSION OF THE DATA PRESENTED IN TABLE 4

Comparing the results from plots 2, 3, and 10 to which nitrogen alone was furnished in the form of nitrate of soda, sulphate of ammonia and cyanamide, respectively, the superiority of nitrate of soda and inferiority of cyanamide are equally remarkable, though, compared with cyanamide, sulphate of ammonia has not much in its favour in point of yield.

Of the cyanamide plots (No. 10) it should be stated that the material, instead of being applied—as usually prescribed—from two to three weeks prior to planting, was applied at seeding time, and on the same date as were the other fertilizer materials used in the experiment. This afforded a striking object lesson relative to the harmful influence exerted by cyanamide, freshly applied, on germination and the development of the young seedling.

Germination was seriously suppressed by the cyanamide, and the stand of plants on these plots was far from uniform. A large proportion of the plants remained spindly throughout the season.

Plots 6 and 8 received—besides phosphoric acid—nitrogen in the form of either nitrate of soda (6) or sulphate of ammonia (8). Here again nitrate of soda takes precedence over sulphate of ammonia by a very considerable margin.

When potash is added to complete the mixture (plots 7 and 9) nitrate of soda still maintains a marked advantage, though somewhat less pronounced than in the other instances. But plot 5, with Nitrapo, is comparable with plots 7 and 9—all having received the same amounts of nitrogen, phosphoric acid and potash.

The small amount by which the yield of plot 5 exceeds that of plot 7 may be deemed within the limits of experimental error. There is no doubt, however, that Nitrapo, by virtue of the ready availability of its nitrogen and potash, has proved itself a valuable concentrated source of these elements of plant food.

SOURCES OF NITROGEN INVESTIGATED AT OTHER STATIONS

It may be of interest to cite results obtained with the same nitrogenous fertilizers on the Ontario Agricultural College Farm at Guelph, and on the Experiment Station at Kingston, Rhode Island.

The Guelph experiments—reported on by Professor Harcourt—were carried out with mangels in the years 1915, 1918 and 1919. As the results of the latter year are typical of those from the former years, the record of the 1919 crop will be given.

At Rhode Island the experimental crop was hay and Bulletin No. 170 of that Station gives the combined yields, during a period of four years (1913-1916), for each plot.

At both Guelph and Rhode Island a uniform quantity of phosphate and potash was applied in conjunction with the nitrogenous fertilizer.

Table 5 permits a comparative study of the results obtained at Charlottetown, Guelph and Rhode Island.

TABLE 5—SOURCES OF NITROGEN—THREE STATIONS

Fertilizers Applied	Charlotte- town Turnips (1921)	Guelph Mangels (1919)	Rhode Island Hay (1913-1916), Four Crops
	Yields per acre	Yields per acre	Yields per acre
	bush.	bush.	tons
Nitrate of soda.....	760.3	841.2	8.88
Sulphate of ammonia.....	492.4	759.2	6.81
Cyanamide.....	410.4	607.2	6.84

At the Rhode Island Station the yields of hay on the sulphate of ammonia and on the cyanamide plots were practically the same, while that on the nitrate of soda plot was nearly 25 per cent greater. Another instance of the superior influence of nitrate of soda, as compared with sulphate of ammonia, on hay, is found in the records of more than half a century from the famous grass plots at Rothamsted, where the sulphate of ammonia plots have been always inferior to those treated with nitrate of soda. In dry seasons the difference is most pronounced, and excavations revealed a deeper penetration of the grass and clover roots in the nitrate plots and explained the greater susceptibility to drought of the grasses on the sulphate of ammonia plots.

To the general rule of nitrate superiority there are, of course, occasional exceptions, and, as indicated already, on soils plentifully provided with lime and with certain crops making their chief vegetative growth comparatively late in the season, sulphate of ammonia may give results not inferior to those from nitrate of soda. Although excessive and continued use of sulphate of ammonia depletes soils of lime, thus creating acidity and necessitating a correction of this condition by means of ground limestone applications, this nitrogenous fertilizer occupies a high place among sources of nitrogen, its merits being well recognized.

"ORCHARD FERTILIZER EXPERIMENT," KENTVILLE, N.S.

The object of this experiment was to ascertain primarily the influence of various fertilizers (furnishing one, two or all three "essential plant food elements") on the development and productiveness of apple trees and on the yields from field crops grown on either side of the tree rows.

The plots are each one-tenth of an acre in area, and the soil is a sandy loam. During the course of the experiment (1913-1921) no manure has been used, the clover aftermath of the third year being depended on to furnish humus. The fertilizers are applied to the first two crops of each rotation or twice in three years. The crop rotation followed is potatoes, grain and clover hay.

Although no data relative to the influence of the fertilizing on the apple trees are available for publication at this juncture, the record of the results from the inter-tilled field crops is interesting and valuable, for it permits a study of the behaviour of the

differently fertilized plots throughout a period of nine years. The third rotation was completed with the harvesting of the hay crop of 1921.

Since this chapter is devoted more particularly to a study of the influence of nitrogen, the grouping of the plots in Table 6 was arranged with this in view.

Where applied, the quantities used were as follow: Nitrate of soda, 150 pounds; superphosphate, 350 pounds; basic slag, 500 pounds; muriate of potash, 150 pounds per acre. These were applied to the first and second crops of each rotation, or six times during the nine year period.

TABLE 6.—INFLUENCE OF NITROGEN IN ROTATION EXPERIMENTS
AT KENTVILLE (1913-1921)

Plot No.	Fertilizers Applied	Potatoes (average of three crops) 1913, 1916, 1919	Yields per Acre Grain (average of one oat crop and two wheat crops) 1914, 1917, 1920	Clover Hay (average of three crop) 1915, 1918, 1921
		bush.	bush.	lbs.
(1)	None (average of four checks).....	148.7	15.9	1,260
10	Nitrate of soda.....	185.9	20.1	2,440
15	Muriate of potash.....	157.9	15.3	2,230
23	Nitrate of soda, muriate of potash.....	183.8	29.4	2,520
21	Basic slag.....	177.2	23.4	4,050
22	Nitrate of soda, basic slag.....	209.2	34.8	5,350
17	Superphosphate.....	162.4	19.2	1,890
24	Nitrate of soda superphosphate.....	188.1	31.5	2,730
20	Superphosphate, muriate of potash.....	179.9	23.1	2,190
16	Nitrate of soda, superphosphate, muriate of potash.....	224.0	33.5	2,360

DISCUSSION OF DATA PRESENTED IN TABLE 6

It will be seen that the fertilizer treatment of the second plot in each pair differs from that of the first only in that nitrate of soda is included.

Therefore, the amount by which the yield of the second exceeds the yield of the first plot is due directly to the influence of nitrate of soda.

In each year and on every crop throughout the entire nine-year period the increased yield produced by nitrate has been considerable.

Of the five groups or pairs the average increase due to nitrate is found to be 33 bushels of potatoes, 10½ bushels of wheat and 856 pounds of clover hay per acre, in each rotation. This increase has been produced through the use of 300 pounds of nitrate of soda, of which 150 pounds was applied to the potato crop and 150 pounds to the grain crop. The pronounced favourable influence of nitrate of soda, seen also in the clover hay yields of the third year, is of especial interest as showing that clover, though deriving much of its nitrogen from the soil atmosphere by means of the root nodule bacteria, responds nevertheless in a marked degree to artificial supplies of readily available nitrogen. Seeing that no applications of fertilizers were made directly to the hay crop, the increase in yield must have been due to the stimulus imparted by the nitrate applied at the time of sowing the grain and clover seed, in the second year of the rotation, rather than to any residue of nitrate remaining in the soil until the third year.

INFLUENCE OF NITRATE MANIFESTED IN THE APPLE TREES

While the trees in this experimental area have not yet reached that mature stage when they might be expected to yield data of value, evidence was not lacking during the drought of 1921 as to the invigorating influence of nitrate of soda. The trees on the nitrate plots, particularly on plot 22 (see Table 6), were conspicuous because of their rich, dark green foliage and their generally healthy appearance.

CHAPTER II

PHOSPHORIC ACID

Phosphoric acid tends more particularly to promote the root development of the young seedling in the early stages and the production of seed or fruit in the more mature stages of growth.

Of crops which respond in a marked degree to liberal applications of phosphoric acid, turnips and tomatoes are notable examples, the one valued for its large root development, the other for its fruit.

It has been assumed—not altogether without warrant—that phosphoric acid is instrumental in advancing the date of crop maturity. In order to discover in what measure this might be attained through an application of phosphoric acid in readily available form, a series of investigations was undertaken, in the years 1919 and 1920, at several stations.

INFLUENCE OF PHOSPHORIC ACID ON CORN AND CEREALS

This investigation was planned and carried out with a view of determining whether and in what degree phosphoric acid, in readily available form, might promote the ripening of corn and cereals.

There exists a widespread belief in this influence of phosphoric acid, which, if well founded, would indicate a means for hastening maturity, and thus permitting the successful growth of certain crops in regions where they might otherwise fail to ripen.

In the year 1919 the investigation was carried out with *Ensilage Corn* on the Experimental Stations at Cap Rouge, Que., Brandon, Man., and Indian Head, Sask.

At each station one plot received superphosphate (containing 16 per cent of available phosphoric acid) at the rate of 400 pounds per acre at Cap Rouge and 300 pounds per acre at Brandon and Indian Head, while an adjoining plot received no fertilizer but was treated otherwise similarly.

In no single instance was there evidence of the phosphoric acid having promoted maturity or increased the yield.

In the year 1920 the investigation was continued with *Wheat* (oats also at Rosthern) on the Experimental Stations at Brandon, Man., Indian Head, Rosthern and Scott, Sask.

At each station the fertilized plot received superphosphate (*acid phosphate*) at the rate of 300 pounds per acre, the adjoining unfertilized plot being treated otherwise similarly.

The wheat on the fertilized plot at Brandon headed out one day earlier than that on the check plot, but this slight advantage had disappeared by the time of harvest. At Scott the wheat on the fertilized plot headed out nearly three days earlier than that on the unfertilized plot and, up to the middle of July, appeared more vigorous, yet both plots ripened at the same time.

Neither at Indian Head nor at Rosthern was a difference in degree of maturity discernible at any time.

In point of yield the results at Rosthern showed increases of one bushel of wheat and two bushels of oats on the fertilized plots—in neither instance sufficient to repay the cost of the superphosphate used. At Brandon and Indian Head both plots produced similar yields, while at Scott the fertilized plot produced 1.3 bushels more grain (wheat) but 340 pounds less straw than the check plot. According to the superintendent, the wheat on the treated plot, which had headed out three days

earlier, was "more affected by extreme heat and less benefited by the late July rains" than the wheat on the check plot.

The results in general, both from corn and cereals, are largely negative in respect to the influence of phosphoric acid in promoting maturity or in increasing yield.

Whether under other seasonal conditions the results would have differed materially from those obtained is a question which further investigations may answer. Evidence from other investigations undertaken on the Experimental Farm System shows that, where available nitrogen is lacking in the soil, a cereal crop may fail to respond to treatment with phosphate and potash until nitrogen in readily available form has been used to satisfy the crop's demand for nitrogen—the element of fertility which probably more often than any other proves to be the limiting factor in crop production.

SOURCES OF PHOSPHORIC ACID

The three chief phosphatic fertilizers are superphosphate (acid phosphate), basic slag and bone meal.

In superphosphate phosphoric acid is present in its most readily available form.

In basic slag the action of the phosphoric acid is somewhat slower, but, partly because of the lime which it contains, and also the form in which its phosphoric acid is present, basic slag may frequently give results superior to those from superphosphate, especially on pastures, grain, clovers and other legumes.

Bone meal contains phosphoric acid in an insoluble organic form which, however, decomposes gradually in the soil, yielding up its phosphoric acid to the soil solution. Under ordinary conditions, bone meal is less active than either superphosphate or basic slag, though, doubtless, its phosphoric acid becomes available eventually.

RELATIVE VALUES OF PHOSPHORIC ACID IN DIFFERENT FORMS

In experiments at three stations, superphosphate was compared with bone meal as a source of phosphoric acid for potatoes. Taking the influence of superphosphate as 100, that of bone meal was as follows: at Charlottetown, 67; at Kentville, 79; at Fredericton, 82.

EXPERIMENTS AT KENTVILLE, N.S.

In this experiment we are able to study, throughout two full crop rotations (1914-1919), the comparative influence of phosphoric acid furnished in three forms, viz., superphosphate, basic slag and bone meal.

In addition to the equivalent of 140 pounds of nitrate of soda and 100 pounds of muriate of potash per acre, phosphoric acid was applied, in Series 3, as superphosphate; in Series 4, as basic slag, and, in Series 5, as bone meal. In each the same amount of phosphoric acid was furnished, and allowance was made for the nitrogen present in the bone meal by reducing proportionally the amount of the concomitant nitrogenous fertilizer.

The fertilizers were applied prior to the commencement of each crop rotation. The soil was described, in 1913, as a light sandy loam, low in fertility and deficient in lime.

Neither at the commencement of, nor during the first rotation was barnyard manure applied. The rotation consisted of (1) *potatoes*, (2) *oats*, (3) *clover hay*.

Since the influence of the liming proved uniformly beneficial, irrespective of the variations made in the fertilizing, discussion of that feature will be reserved for Chapter 5.

TABLE 7.—SOURCES OF PHOSPHORIC ACID—KENTVILLE, N.S.

FIRST ROTATION, 1914-1916

Plot	Phosphatic Fertilizer (used in addition to Nitro- gen and Potash)	Yields per Acre (averages of quadruplicate plots)				Increase over Checks			
		Pota- toes (1914)	Oats (1915)		Hay (1916)	Pota- toes (1914)	Oats (1915)		Hay (1916)
			Grain	Straw			Grain	Straw	
		bush.	bush.	lbs.	lbs.	bush.	bush.	lbs.	lbs.
3	Superphosphate, 300 lbs.....	87.1	34.4	1,950	935	25.4	2.8	305	20
4	Basic slag, 300 lbs.....	88.7	35.8	2,150	1,255	27.0	4.2	505	340
5	Bone meal, 240 lbs.....	74.0	35.9	1,930	1,005	12.3	4.3	285	90
6	No fertilizer (check).....	61.7	31.6	1,645	915	.....	.....	.....	.....

Owing to the low original fertility of the area, the fact that no barnyard manure was employed and that the fertilizer applications were light, the yields throughout the first crop rotation are sub-normal. Nevertheless, distinct differences in the response to the three sources of phosphoric acid are noticeable. Superphosphate and basic slag were fairly uniformly influential with potatoes in the first year, bone meal having proved very much less so. However, as the bone residue decomposes in the soil, we find bone meal on a par with the others in the production of grain in the second year.

Basic slag gives the greatest yield of straw and, again, of clover hay in the third year. Over the three-year period basic slag has proved the most, and bone meal the least profitable source of phosphoric acid. By virtue of the lead gained over bone meal in the potato crop of the first year, superphosphate maintains the advantage, though in only a slight degree, at the close of the period.

At the conclusion of the first rotation, the whole area devoted to this experiment received a uniform application of barnyard manure at the rate of 15 tons per acre.

The fertilizer treatment of 1914 was repeated at the commencement of the second rotation in the year 1917. In the second rotation wheat replaced oats as the grain crop.

TABLE 8.—SOURCES OF PHOSPHORIC ACID—KENTVILLE, N.S.

SECOND ROTATION, 1917-1919

Plot	Phosphatic Fertilizer (used in addition to Nitro- gen and Potash)	Yields per Acre (averages of quadruplicate plots)				Increases over Checks			
		Pota- toes (1917)	Wheat (1918)		Hay (1919)	Pota- toes	Wheat (1918)		Hay (1919)
			Grain	Straw			Grain	Straw	
		bush.	bush.	lbs.	lbs.	bush.	bush.	lbs.	lbs.
3	Superphosphate, 300 lbs.....	310.2	27.0	2,325	3,885	27.6	2.4	205	520
4	Basic slag, 300 lbs.....	317.9	28.3	2,150	4,235	35.3	3.7	30	870
5	Bone meal, 240 lbs.....	309.0	27.1	2,535	4,065	26.4	2.5	415	700
6	No fertilizers (Check).....	282.6	24.6	2,120	3,365	.....	.....	.....	.....

In the second rotation the yields are higher generally than in the first, as will be apparent on comparing the figures in Table 7 with those in Table 8. This is due unquestionably to the application of manure which preceded the second rotation.

Basic slag has again in this rotation proved the most profitable phosphatic fertilizer. Bone meal, due doubtless to its slower or deferred influence, has proved equal to superphosphate in the second rotation and but slightly inferior over the six-year period.

EXPERIMENTS AT FREDERICTON, N.B.

This experiment ran concurrently (1914-1916) with the first rotation of the experiment, similarly named, at Kentville. The soil of the area devoted to the experiment at Fredericton was described as a medium loam with clay subsoil.

The rotation followed was (1) *potatoes*, (2) *oats*, and (3) *clover hay*. In addition to the equivalents of 140 pounds of nitrate of soda and 100 pounds of muriate of potash per acre, plots 3, 4 and 5 (all in duplicate) received phosphoric acid in the forms of superphosphate, basic slag and bone meal, respectively.

The yields of the three crops in the rotations are represented in Table 9.

TABLE 9.—SOURCES OF PHOSPHORIC ACID, FREDERICTON, N.B.

CROP ROTATION, 1914-1916

Plot No.	Phosphatic Fertilizer (used in addition to Nitrogen and Potash)	Yields per Acre (averages of duplicate plots)			Increase over Check		
		Potatoes (1914)	Oats (1915)	Hay (1916)	Potatoes (1914)	Oats (1915)	Hay (1916)
		bush.	bush.	lbs.	bush.	bush.	lbs.
3	Superphosphate, 300 lbs.....	320.3	57.0	4,310	135.0	25.2	1,020
4	Basic slag, 300 lbs.....	261.0	68.2	6,180	75.7	36.4	2,890
5	Bone meal, 240 lbs.....	229.7	55.3	4,490	44.4	23.5	1,200
6	No fertilizers (Check).....	185.3	31.8	3,290	.....	.....	.....

The data recorded in Table 9 show that with the potato crop of the first year superphosphate proved the most potent source of phosphoric acid, basic slag taking second and bone meal third place.

In the oat crop of the second year basic slag takes the lead and increases its advantage in the clover hay crop of the third year.

This accords with common experience. Superphosphate proves usually superior to basic slag as a source of phosphoric acid for potatoes, but slag usually surpasses superphosphate in its influence on the oat crop, and proves almost invariably superior for clover hay.

Whether superphosphate or basic slag has proved most profitable at the close of the three-year rotation would be decided by the relative value of the produce. Superphosphate has nearly 60 bushels more potatoes to its credit in the first year, as compared with 11.2 bushels more oats and 1,870 pounds more hay to the credit of basic slag in the second and third year.

As in the experiment at Kentville, bone meal proved inferior to superphosphate and basic slag in the first year, but equalled superphosphate in its influence during the second and third years.

INFLUENCE OF PHOSPHORIC ACID AT AGASSIZ

In Table 10 data from the Experimental Farm at Agassiz, indicate the effect of increasing the quantity of phosphoric acid in the fertilizer.

Three pairs of plots are represented in the table, the first of each pair having received double the quantity of superphosphate applied to the second plot of the same pair.

TABLE 10.—INCREASING THE PHOSPHORIC ACID IN THE FERTILIZER, AGASSIZ, B.C., 1918

Plot No.	Fertilizer Treatment (in lbs. per acre)			Yields per Acre		
	Nitrate of Soda	Super- phosphate	Muriate of Potash	Mangels (1918)	Oats (1919)	
					Grain	Straw
				bush.	bush.	lbs.
2A.....	266	1,000	320	804.0	22.4	1,720
4A.....	266	500	320	794.4	25.9	1,760
5A.....	533	1,000	160	744.8	17.6	1,440
7A.....	533	500	160	728.8	20.0	1,600
2C.....	133	500	160	648.9	22.4	1,320
4C.....	133	250	160	578.4	16.5	1,360

It will be noted that but slight increases followed the doubling of the quantity of superphosphate in the first two instances (9.6 and 16 bushels of mangels per acre), while in the oat crop of the second year an actual decrease is shown. But the results from plots 2 C and 4 C—where 500 and 250 pounds, respectively, of superphosphate are compared—indicate that the smaller quantity was inadequate, the returns showing increases of 70.4 bushels of mangels and 6 bushels of oats per acre from the heavier application (500 pounds) of superphosphate.

That 500 pounds of superphosphate per acre represents the maximum profitable application for mangels is indicated by the results obtained from other plots of the same experiment. The highest yield of mangels, was obtained on plot 3 A which—in conjunction with the maxima nitrogen and potash applications—received superphosphate at the rate of 500 pounds per acre. A more profitable yield, however, was obtained with but 375 pounds of superphosphate in addition to 400 pounds of nitrate of soda and 240 pounds of muriate of potash per acre.

EXPERIMENTS AT KAPUSKASING, ONT.

This experiment was commenced at the Experimental Station of Kapuskasing, Ont., in the year 1920. The soil is a silty clay. In the fall of 1919 the whole area received barnyard manure at the rate of 20 tons per acre.

In the section to be considered at present basic slag (containing 10 per cent of total phosphoric acid) alone was applied at the rates of 500, 750 and 1,000 pounds per acre.

Table 11 gives the results on the potato crop of 1920 and succeeding barley crop of 1921.

TABLE 11.—VARYING QUANTITY OF BASIC SLAG, KAPUSKASING, ONT. (1920-21)

Plot No.	Basic Slag (in addition to 20 tons of manure per acre, applied in 1920)	Yields per Acre		Increase over Check	
		Potatoes (1920)	Barley (1921)	Potatoes (1920)	Barley (1921)
	lbs.	bush.	bush.	bush.	bush.
1	Manure alone (check).....	120.0	25.0	.....	.....
2	Basic slag, 500.....	133.3	26.9	13.3	1.9
3	“ 750.....	158.3	27.7	38.3	2.7
4	“ 1,000.....	160.0	28.5	40.0	3.5

The results recorded in Table 11 show that on the potato crop 750 pounds of basic slag increased the yield by 38.3 bushels per acre, as compared with an increase of only 13.3 bushels produced by the 500 pounds application.

But the further augmentation of the slag application, to 1,000 pounds per acre, accounts for less than 2 bushels further increase in crop.

Owing to the exceedingly dry season of 1921, the yields of barley are subnormal and the influence of the fertilizer residues is not very pronounced. It is, nevertheless, discernible and regular, the increases being in direct proportion to the amounts of basic slag applied in the former year.

It is possible that the returns from the hay crop of 1922 may show the heaviest application of basic slag, on plot 4, to have been most profitable over the three-year period. Experience leads us to expect the chief influence of basic slag to be manifested in the hay crop.

CHAPTER III

POTASH

Potash is instrumental in the formation of carbohydrates—starches, sugars and fibre—within the plant. It is, therefore, a plant food substance of special importance for potatoes, sugar beets, mangels, flax and tobacco.

The potassic fertilizers finding most extensive employment in Canada are muriate of potash and sulphate of potash, each containing about 50 per cent of actual potash soluble in water. Kainit, a crude potash salt, containing about 12½ per cent of potash, has been used to a limited extent in the Maritime Provinces, but the more concentrated salts—muriate and sulphate—find more favour. Of these muriate of potash is the more popular; sulphate of potash is preferred for tobacco, and by some has been considered preferable to muriate for potatoes and sugar beets also.

Wood ashes represent a domestic source of potash. If unleached, they may contain from 4 to 6 per cent of potash as carbonate of potash.

Sandy and peaty soils are usually deficient in potash and most crops grown on these light soils will respond to applications of potash in some form.

INFLUENCE OF POTASH ON MANGELS AND OATS AT AGASSIZ, B.C.

In the sandy loam soil which overlies a gravelly subsoil on the Experimental Farm of Agassiz, B.C., potash is naturally deficient, and a special feature of the results from soil fertility investigations there has been the remarkable response of crops to potassic fertilizers.

Experiment E, introduced there in the year 1918, contained provisions for measuring the influence of potash. In Table 12, the data from nine plots, arranged in groups of three, show the depressing effect on the yields of both mangels and oats of decreasing the quantity of potash in the fertilizer.

The whole area received manure at the rate of 10 tons per acre in the fall of 1917. The fertilizers were applied in the spring of 1918 for the mangel crop, no further application being made for the oat crop of 1919.

As Table 12 shows, the second plot of each group received half the quantity of potash applied to the first, while from the fertilizing of the third plot potash was omitted entirely.

Otherwise, the fertilizing within each individual group was the same.

TABLE 12.—VARYING THE QUANTITY OF POTASH IN THE FERTILIZER,
AGASSIZ, B.C. (1918-1919)

Plot No.	Fertilizer Treatment in 1918 (in pounds per acre)			Yields per Acre		
	Nitrate of Soda	Super- phosphate	Muriate of Potash	Mangels (1918)	Oats (1919)	
					Grain	Straw
				Bush.	Bush.	Lbs.
2A.....	266	1,000	320	804.0	22.4	1,720
6A.....	266	1,000	160	664.8	20.0	1,800
12A.....	266	1,000	.....	558.4	11.2	820
3A.....	533	500	320	916.8	25.3	1,540
7A.....	533	500	160	728.8	20.0	1,600
13A.....	533	500	.....	620.0	15.3	1,240
2B.....	200	750	240	785.6	28.2	1,360
6B.....	200	750	120	658.8	20.0	1,560
12B.....	200	750	.....	553.6	10.6	1,320

Comparing the behaviour of the plots within each group, one notes that the yields correspond very closely to the amount of potash supplied. That is to say, diminishing yields of both mangels and oats followed consistently the reduction of potash in the fertilizer.

The influence of the potash residue, clearly marked in the oat yields of the second year, contrasts strongly with that of phosphoric acid residues. Indeed under the very adverse seasonal conditions which obtained at Agassiz, in 1919, phosphoric acid in very large quantities would seem to have proved inimical to the grain crop. The pertinence of this remark will be apparent on referring to Table No. 10 in Chapter 2.

Incidentally, it may be observed, on comparing the yields of mangels in the several groups, that with the larger applications of nitrate of soda, the yields were consistently greater.

INFLUENCE OF POTASH AT KAPUSKASING, ONT. (1920-1921)

On a silty clay soil at the Experimental Station of Kapuskasing, Ont., one might scarcely have expected any notable response to potash in the fertilizer. The results represented in Table No. 13, show, however, that potash was responsible for substantial gains in the yields of both potatoes and barley.

In the fall of 1919 the whole area received manure at the rate of 20 tons per acre. This liberal manuring, contributing a large quantity of potash to the soil, makes the influence of potash in the fertilizer all the more remarkable.

The fertilizers were applied in 1920, in which year a crop of *potatoes* was grown, followed by a crop of *barley* in 1921.

TABLE 13.—INFLUENCE OF POTASH AT KAPUSKASING (1920-21)

Plot No.	Fertilizers applied 1920 (in pounds per acre)				Yields per acre			
	Nitrate of Soda	Super- phosphate	Basic Slag	Muriate of Potash	(Potatoes 1920)		Barley (1921)	
					—	Average Yield of plots 31 and 33	—	Average Yield of plots 31 and 33
					bush.	bush.	bush.	bush.
9.....	100	200	200	.....	137.0	.....	30.8	.....
31.....	100	200	200	100	169.3	168.0	36.8	36.5
33.....	100	200	200	100	166.7	.....	36.2	.....

As supplemental to the manuring, all three plots, shown in Table 13, received a fertilizer compounded of nitrate of soda, superphosphate and basic slag. In addition to this treatment, plots 31 and 33 received muriate of potash at the rate of 100 pounds per acre. Plot 29 received no potash in the fertilizer. The results are consistent and convincing. On comparing the average yields of plots 31 and 33 with those of plot 29, 100 pounds of muriate of potash is found to have increased the yields by 31 bushels of potatoes and 5.7 bushels of barley per acre.

The severe drought experienced in the summer of 1921 undoubtedly depressed the yields of barley. Notwithstanding, the influence of the potash extended to the second year in a very marked degree. In this respect, results are very similar to those obtained at Agassiz in the season of 1919 (see Table 12).

INFLUENCE OF POTASH AT CHARLOTTETOWN, P.E.I. (1921)

In Chapter 1, the data furnished by the "Sources of Nitrogen Experiment" at Charlottetown were discussed primarily in respect to the influence of nitrogen. The

plan of the experiment provided also for testing the influence of potash, applied in conjunction with superphosphate and with different nitrogenous materials.

No manure was applied in this experiment.

The soil was a medium loam of good tilth and of moderate fertility. The crop was Swede Turnips. In Table 14 the plots are arranged in groups of two, so as to facilitate a comparison of those which differ only in that one of each pair has received potash in addition to the other fertilizing.

TABLE 14.—INFLUENCE OF POTASH ON TURNIPS AT CHARLOTTETOWN, P.E.I. (1921)

Plot No.	Fertilizer Materials (in pounds per acre)	Elements furnished	Yield per acre Swede Turnips	Increase due to Potash
			bush.	bush.
1	Nitrapo.....200	Nitrogen and potash.....	805.6	
2	Nitrate of soda.....200	Nitrogen.....	790.8	14.8
5	Nitrapo.....200 Superphosphate.....300	Nitrogen, phosphoric acid and potash...	899.6	
6	Nitrate of soda.....200 Superphosphate.....300	Nitrogen..... Phosphoric acid.....	757.2	142.4
7	Nitrate of soda.....200 Superphosphate.....300 Muriate of potash.....60	Nitrogen, phosphoric acid and potash....	876.8	
6	Nitrate of soda.....200 Superphosphate.....300	Nitrogen and phosphoric acid.....	757.2	119.6
9	Sulphate of ammonia....150 Superphosphate.....300 Muriate of potash.....60	Nitrogen, phosphoric acid and potash....	813.6	
8	Sulphate of ammonia....150 Superphosphate.....300	Nitrogen and phosphoric acid.....	588.4	225.2

The nitro-potassic fertilizer, "Nitrapo," employed in these experiments, has been described in Chapter I. It contains 15 per cent each of nitrogen and potash, so 100 pounds of Nitrapo represents the equivalent of 100 pounds of nitrate of soda plus 30 pounds of muriate of potash.

On plots 1 and 5 the potash was furnished by "Nitrapo"; on plots 7 and 9 by muriate of potash.

By comparing the yields from plots 1 and 2 where Nitrapo and nitrate of soda respectively were applied without superphosphate, it will be seen that the increase, which may be attributed to the potash in the Nitrapo, was slight—only 14.8 bushels per acre and within the limits of experimental error. With superphosphate Nitrapo (plot 5) shows more plainly the value of the potash as compared with the no potash plot (6).

Like results are noticeable when potash is furnished in the form of muriate on plots 7 and 9. On comparing the yields from plots 8 and 9 a very large difference is found in favour of the potash. Plot 8 (sulphate of ammonia with superphosphate), however, produced a very low yield. This, though in less degree, is true also of the behavior of plot 5 (nitrate of soda with superphosphate) which produced a yield smaller than that from plot 2, with nitrate of soda alone.

Despite these apparent inconsistencies, the influence of potash has been unmistakable throughout and, on a crop (turnips) which does not usually respond in any marked degree to artificial supplies of potash. This is true more particularly when manure—according to the usual custom—is applied. The omission of manure in this experiment may account in part for the potency of the potash applied.

INFLUENCE OF POTASH IN KENTVILLE ROTATIONS (1913-1921)

It may be considered somewhat remarkable that on the light sandy loam soil of the Experimental Station at Kentville potash should prove of relatively small importance as compared with that of nitrogen and phosphoric acid in crop production.

In the "Orchard Fertilizer Experiment" it has been possible to observe during a period of nine years, or three crop rotations, the behaviour of three plots fertilized similarly in respect to nitrogen and phosphoric acid but receiving varying amounts of potash.

Neither at the commencement of, nor during the nine years' course of the experiment has manure been applied. Applications of fertilizers have been made twice—to the potato and grain crops—during each rotation.

Table 15 presents in succession the data from each three-crop rotation, the fourth section of the table giving the average yields from each plot for three rotations covering a nine-year period.

TABLE 15.—INFLUENCE OF POTASH IN ROTATIONS AT KENTVILLE, N.S., (1913-1921)

Plot No.	Fertilizers (total of two applications) applied in each rotation, per acre			Yields per acre		
	Nitrate of Soda	Super-phosphate	Muriate of Potash	Potatoes	Oats	Hay
FIRST ROTATION (1913-1915)						
	lbs.	lbs.	lbs.	bush.	bush.	lbs.
13.....	300	700	60	164.0	55.3	2,840
9.....	300	700	120	213.0	54.0	3,080
5.....	300	700	200	172.5	53.6	2,540
SECOND ROTATION (1916-1918)						
					Wheat	
13.....	300	700	60	206.5	18.5	945
9.....	300	700	120	240.0	15.0	975
5.....	300	700	200	226.0	15.7	915
THIRD ROTATION (1919-1921)						
13.....	300	700	60	231.7	20.3	2,600
9.....	300	700	120	252.7	19.0	1,980
5.....	300	700	200	244.5	18.3	2,060
AVERAGES FOR THREE ROTATIONS (1913-1921)						
13.....	300	700	60	200.7	31.4	2,130
9.....	300	700	120	235.2	29.3	2,010
5.....	300	700	200	214.3	29.2	1,840

DISCUSSION OF THE DATA PRESENTED IN TABLE 15

At Kentville we have several soil fertility investigations which have been carried on systematically and consistently for a number of years, and by virtue of time, which may be expected to overcome or modify the influence of obtrusive disturbing factors, are invested with a special authoritative value.

It is possible that the three plots (13, 9 and 5) differed slightly one from another in respect to soil conditions. But, on a light soil of this nature, especially in the

absence of manure, one might have expected to discover, before the lapse of nine years, a relatively greater degree of response to potash on the plots receiving the more liberal supply of that substance.

It will be noted that, except on the potato crops of the first year, plot 13, receiving only 60 pounds of muriate of potash in each rotation, produced yields superior to those from plot 9 which received double the quantity of potash. In grain yields plot 13 has led throughout; in the first and second hay crops it was slightly behind plot 9, though decidedly in the lead with the hay crop of 1921.

However, because of the marked superiority of the potato crops on plot 9, the additional potash used has proved distinctly profitable. The further increase in the quantity of potash, on plot 5, which received 200 pounds of muriate in each rotation, has not been justified by results.

The relative behaviour of plots 13 and 9 is quite consistent with experience when one considers the usual response of a potato crop to potash in the fertilizer. While both plots may be said to have given results fairly uniform with other crops, plot 9 has always produced a considerably heavier yield of potatoes than that from plot 13.

But a closer examination of the data reveals the fact that the difference between the potato yields on plots 13 and 9 is steadily diminishing.

In the year 1913 the yield of potatoes on plot 9 exceeded the yield of plot 13 by 49 bushels per acre; in 1918 the difference was $33\frac{1}{2}$ bushels, and in 1919, 21 bushels. Stated otherwise, if the yield of plot 9 in each year be taken as equal to 100, that of plot 13 would be as 77, 86 and 91 in the potato-crop years 1913, 1916 and 1919, respectively.

From this it might appear that even the small quantity of potash furnished by 60 pounds of muriate in each rotation contributes to the accumulation of a reserve supply of potash in the soil, which may be utilized by the recurring potato crop.

While these results from Kentville experiments are exceptional in that they show such an indifferent response by crops to potash on a sandy loam soil, they indicate the necessity for appealing directly to the soil for the solution of its special fertility problems and the impossibility of determining its fertilizer needs with any degree of accuracy from a mere knowledge of its general characteristics.

CHAPTER IV

A COMPARISON OF MINERAL WITH ORGANIC FERTILIZERS

In chapter II some details are given of experiments comparing superphosphate and bone meal, the one a mineral and the other an organic source of phosphoric acid.

PHOSPHORIC ACID FROM BONE

The results following (1) a one-year trial at Charlottetown, Kentville and Fredericton, (2) a three-year trial at Fredericton and (3) a six-year trial at Kentville, showed that superphosphate by virtue of the readier availability of its phosphoric acid proved in the early stages distinctly superior to the more slowly acting bone meal. However, with the lapse of time the phosphoric acid liberated gradually from the decomposing bone became more effective and it was noted that during the second rotation at Kentville the influence of the bone meal was practically equal to that of superphosphate.

NITROGEN FROM ORGANIC SOURCES

NITRATE OF SODA VERSUS WHALE GUANO AT AGASSIZ, B.C.

At the Experimental Farm at Agassiz, B.C., in the year 1918, whale guano—a by-product of the Pacific whaling industry—was compared with nitrate of soda as a source of nitrogen in fertilizers for corn and mangels.

In point of nitrogen content (12·5 per cent) whale guano compares favourably with dried blood, the most highly esteemed of the organic sources of nitrogen. As a matter of fact, whale guano contains a very considerable amount of blood.

Comparisons were made (1) on the basis of nitrogen content—180 pounds of whale guano being, in this respect, equivalent to 150 pounds of nitrate of soda—and (2) on the basis of commercial value—265 pounds of whale guano representing (in 1918) the money equivalent of 150 pounds of nitrate of soda.

In the experiment, therefore, one plot received nitrate of soda and two plots whale guano. Besides the nitrogenous fertilizer each of the plots was treated with superphosphate at the rate of 350 pounds per acre. On one plot the nitrogen was omitted, superphosphate alone being applied.

In these respects the treatment of both corn and mangel areas was the same; but in the corn experiment an unfertilized plot was included.

In another somewhat poorer part of the mangel field an unfertilized check plot adjoined a plot fertilized with 150 pounds of nitrate of soda and 350 pounds of superphosphate per acre. Though not strictly comparable with the other mangel plots, the data therefrom have a contributory interest and will be recorded in a subsection of Table 17.

TABLE 16.—NITRATE OF SODA VERSUS WHALE GUANO ON ENSILAGE CORN, 1918

Plot No.	Fertilizers (in pounds per acre)			Yields per acre (duplicate plots Corn Ensilage)	Increase	
	Nitrate of Soda (15% N)	Whale Guano (12½% N)	Super- phosphate (17% P ₂ O ₅)		Over Check Plot	No Nitrogen Plot (1)
				tons	tons	tons
1.....	No ni	trogen	350	14·2	2·9	—
2.....		180	350	14·3	3·0	0·1
3.....	150	.....	350	15·3	4·0	1·1
4.....		265	350	13·6	2·3	0·6
5.....	Check—No	fertilizers.....		11·3		

The data in Table 16 indicate that whale guano (plots 2 and 4) in this instance proved quite ineffective, whereas 150 pounds of nitrate of soda was responsible for over a ton per acre increase in the yield of ensilage corn.

The experiment with mangels in the same year (1918) was carried out on a plan similar to that for the preceding one, except that in the first section no unfertilized check was present.

TABLE 17.—NITRATE OF SODA VERSUS WHALE GUANO ON MANGELS (1918)

Plot No.	Fertilizers (in pounds per acre)			Yields per acre (duplicate plots Mangels)	Increase over "No nitrogen Plot" (1)
	Nitrate of Soda (15% N)	Whale Guano (12½% N)	Super- phosphate (17% P ₂ O ₅)		
				Bush.	Bush.
1.....	No nitrogen		350	830.8	—
2.....		180	350	828.3	-2.5
3.....	150		350	1,002.0	171.2
4.....		265	350	864.7	33.9
					Increase over Unfertilized Check
1 A.....	150		350	904.8	709.1
2 A.....	Check—No	fertilizers.		195.7	—

In the mangel experiment plot 4, with the heavier application of whale guano, shows an increase in yield of approximately 34 bushels over the no-nitrogen plot, No. 1, whereas plot 2, like the whale guano plots of the corn experiment, shows no increase. Again the value of the more immediately available nitrogen in nitrate of soda is reflected in the yield from plot 3, which is over 170 bushels greater than that from the no-nitrogen plot.

As remarked already, the area occupied by plots 1 A and 2 A was some distance removed from the other, and supposedly of somewhat inferior tilth, so that the two plots are strictly comparable only between themselves. The results, however, have a wider application as indicating and confirming the consistency of the influence exerted on the crop yields, throughout these experiments, by the nitrate of soda and superphosphate.

The low yield of mangels on the unfertilized plot, 2 A, is by no means exceptional, but, as will be shown later, quite consistent with the results from several years' investigation with the mangel crop at Agassiz.

NITRATE NITROGEN VERSUS DRIED BLOOD, AT OTTAWA

At the Central Experimental Farm, Ottawa, an investigation carried out in the year 1918 with the primary object of ascertaining the fertilizing value of nitrate of lime—known otherwise as Norwegian Saltpetre—embraced in its scheme a plot on which nitrogen in the form of dried blood was employed.

Nitrate of lime, like cyanamide, is the product of an electrical process in which, at very high temperatures, atmospheric nitrogen is induced to combine with lime. As indicated by its name, it is a product of Norway. A further description of the material will be found in a subsequent chapter.

Equivalent amounts of nitrogen (30 pounds per acre) were furnished as nitrate of soda, nitrate of lime and dried blood, each being applied in conjunction with 400 pounds of superphosphate and 75 pounds of muriate of potash per acre, as the following table shows. The soil of the experimental area is a medium loam. The crop was potatoes of the Irish Cobbler variety.

TABLE 18.—NITRATE NITROGEN VERSUS ORGANIC NITROGEN, OTTAWA, 1918

Plot No.	Fertilizers, in pounds per acre					Yields per acre Potatoes	Increase over Check Plot	Increase over No Nitrogen Plot (4)
	Nitrogenous Materials			Super- phosphate (16% P ₂ O ₅)	Muriate of Potash (50% K ₂ O)			
	Nitrate of Soda (15% N)	Nitrate of Lime (12% N)	Dried Blood (11½% N)					
						bush.	bush.	bush.
1.....	200			400	75	290.0	73.3	37.3
2.....		250		400	75	282.5	65.8	29.8
3.....			260	400	75	249.5	32.8	-3.2
4.....				400	75	252.7	36.0	—
5.....	Check—	No fertiliz	ers.....			216.7		

As will be seen on comparing the yields of plots 3 and 4, nitrogen in the organic form of dried blood was in this particular instance quite ineffectual, whereas in the more readily available forms of nitrate of soda and nitrate of lime its influence was very marked. The relative influence of the three sources of nitrogen may be most readily observed in the figures given in the last column of Table 18. These represent the increases over the yield of plot 4 which, except that it received no nitrogen, was fertilized similarly to the other plots.

Nitrate of lime gave results substantially the same as those from the use of nitrate of soda. The close agreement of the data furnished by these plots (1 and 2) emphasizes the usually greater efficiency of immediately available nitrogen as compared with that from organic sources.

It is rather unusual, however, to find dried blood so unproductive of results, for of organic sources of nitrogen it is recognized generally as the most active.

With regard to the amounts of phosphoric acid and potash furnished in this experiment, the former is somewhat higher and the latter considerably lower than might be deemed desirable in a suitably balanced fertilizer for potatoes. At the time the limited stock of potash on hand precluded a full application, which would otherwise have been at the rate of 150 pounds of muriate of potash per acre, while the immediate need for available phosphoric acid would have been met probably by 300 pounds of superphosphate.

MINERAL VERSUS ORGANIC SOURCES OF NITROGEN AND PHOSPHORIC ACID AT AGASSIZ, B.C.

Certain important features of Experiment E at Agassiz, have been discussed in previous chapters, and the prevailing conditions of soil, season, etc., described.

The section of Experiment E now engaging our attention was introduced for the purpose of studying the behavior of plots receiving fertilizer mixtures containing nitrogen and phosphoric acid (1) derived wholly from mineral sources, (2) partly from mineral and partly from organic, and (3) entirely from organic sources.

The mangel crop of 1918—to which the fertilizers were applied—was succeeded in 1919 by an oat crop.

Though the sources of each were varied, the amounts of nitrogen and phosphoric acid furnished were the same—60 and 120 pounds per acre, respectively—on each plot.

TABLE 19.—MINERAL VERSUS ORGANIC SOURCES OF NITROGEN AND PHOSPHORIC ACID

Plot No.	Fertilizer Treatment (1918) (furnishing in each instance 60 lbs. of Nitrogen and 120 lbs. of Phosphoric Acid per acre)	Yields per acre		
		Mangels (1918)	Oats (1919)	
		bush.	bush.	lbs.
16 B.....	All Mineral Fertilizer. All nitrogen from Nitrate; half phosphoric acid from Superphosphate, half from Basic Slag.....	859.2	20.0	1,840
18 B.....	Part of nitrogen from Nitrate, part from Tankage; half phosphoric acid from Superphosphate, half from Tankage.	452.8	28.2	1,440
19 B.....	Most of Nitrogen and all Phosphoric acid from Tankage.....	304.0	20.0	1,480
20 B.....	All Organic Materials —Blood, Tankage and Bone meal.....	152.0	18.8	1,600
Checks....	Average of 4 unfertilized plots.....	22.4	18.4	1,745

DISCUSSION OF FEATURES AND DATA PRESENTED IN TABLE No. 19

By gradual steps from an all mineral fertilizer on plot 16 B an all organic fertilizer is reached in plot 20 B.

In plot 18 B half the phosphoric acid and in plot 19 B all the phosphoric acid is furnished by tankage. The latter was in the nature of a bone tankage, having about 5.75 per cent of nitrogen and 15 per cent of phosphoric acid. While furnishing the whole quota of phosphoric acid on plot 19 B, the tankage did not satisfy fully the nitrogen requirements, so a small amount of nitrate of soda was used to adjust the balance.

On plot 20 B organic materials (all abattoir by-products) were used exclusively. Phosphoric acid was derived equally from tankage and bone meal, while dried blood supplied what the tankage and bone lacked of the total nitrogen quota.

The marked decline in the yield of mangels, as the mineral fertilizers are replaced gradually by organic materials, is very striking.

With the exception of plot 16 B which gave a grain yield lower than that from 18 B—though producing the heaviest yield of straw—the same gradual decline is noticeable in the oat crop of the second year.

The cause of the abnormally low yields of grain is found in the untoward seasonal conditions described in the history of Experiment E, as recorded in Chapter 1.

The extraordinary difference between the average yield of the check plots and the yields of the fertilized plots manifested in the mangel crop is not apparent in the oat crop of the second year. It is quite evident that the unfavourable seasonal conditions prevented the crop from utilizing the phosphatic and potassic fertilizer residues in the soil. That lack of available nitrogen proved the limiting factor has been clearly shown in the results recorded in Chapter 1.

CHAPTER V

MANURE IN CONNECTION WITH FERTILIZERS AND LIME

INFLUENCE OF MANURE AT KENTVILLE, N.S.

In the Fertilizers and Lime experiment at the Experimental Station of Kentville, N.S., the favourable influence of manure on this sandy loam soil is very plainly discernible on comparing the yields of the first rotation (1914-1916) with those of the second (1917-1919).

The comparison in respect to the grain crops in the second year of each rotation is somewhat restricted by the fact that one is oats and the other wheat. However, when allowance is made for the difference in their normal yielding capacity, the greater productiveness of the area in each year of the second rotation will be perceived.

No manure was employed in the first rotation. At its conclusion, in the fall of 1916, the whole area received a uniform application of manure at the rate of 15 tons per acre.

Table No. 20 presents the average yields from all plots of the experiment (a) in the first and (b) in the second rotation.

TABLE 20.—INFLUENCE OF MANURE IN KENTVILLE ROTATIONS (1914-1919)

	Yields per acre			
	Potatoes	Oats		Clover Hay
		Grain	Straw	
	bush.	bush.	lbs.	lbs.
A. Unmanured in First Rotation.....	71.6	33.3	1,830	995
B. Manured in Second Rotation.....	296.7	25.8	2,215	3,695

These results need no comment; they typify general experience of the value of manure, particularly on light soils.

Not only did manure increase the productiveness of the area; it increased also the efficacy of the fertilizers and rendered their use more profitable in the second than in the first rotation.

INFLUENCE OF MANURE AT AGASSIZ, B.C.

Records of the results from the use of barnyard manure on the light soil at Agassiz have been rather at variance with those of general experience.

The area devoted to Experiment E, commenced at Agassiz, B.C., in 1918, was (in the fall of 1917) treated to a uniform light application of manure at the rate of 10 tons per acre. Only one plot—the Permanent Check Plot—received no manure. Some received a supplemental application of 5 tons and one plot received 20 tons of manure per acre. The results yielded by comparable plots are recorded in Table No. 21.

TABLE 21.—INFLUENCE OF MANURE AT AGASSIZ, B.C., 1918-1919

Plot No.	Manure in Tons per acre	Fertilizers (in pounds per acre) Applied in 1918			Yields per Acre			
		Nitrate of Soda	Super- phosphate	Muriate of Potash	Mangels (1918)	Mangels Increase Due to Manure	Oats (1919)	
							Grain	Straw
					bush.	bush.	bush.	lbs.
6B.....	10	200	750	120	658.0	.....	20.0	1,560
9B.....	15	200	750	120	760.0	102.0	16.5	1,520
11C.....	10	266	500	.....	641.6	.....	14.7	1,500
14A.....	15	266	500	.....	756.0	114.4	20.0	1,920
12B.....	10	200	750	.....	553.6	.....	10.6	1,320
15B.....	15	200	750	.....	748.0	194.4	15.3	2,280
21A.....	20	No Fertilizers			91.2	68.8	24.1	1,860
21B.....	15	" "			44.0	21.6	15.9	1,220
Checks (average).....	10	No Fertilizer			22.4	22.4	18.4	1,745
Permanent check plot.....		Neither Manure nor Fertilizers.			nothing	.....	11.8	1 400

The yields of mangels recorded from the first three pairs of plots indicate a reasonable increase from the additional 5 tons of manure applied in conjunction with the fertilizers the difference in favour of the extra manure having been more marked where nitrogen was lower and potash entirely lacking in the fertilizer.

Where manure was applied without fertilizers (see the lower section of Table 21) the yields of mangels have been extremely small. There is, however, a fairly regular increase as the application of manure is advanced to 20 tons. The permanent check plot, which received neither manure nor fertilizer, produced no crop.

The data from the second year show that on plots of the second, third and fourth groups increases in the yields of oats may be credited to manure. It is evident, however, that owing to adverse seasonal conditions, all the results for this year (1919) are exceptionally low and not to be regarded as illustrative of the normal effects of manure and fertilizers.

LIME AS A SUPPLEMENT TO MANURE AND FERTILIZERS

Of the three usual forms—*quick lime*, *slaked lime* and *ground limestone*—in which lime may be applied to the soil for the purpose of (a) correcting acidity, (b) improving tilth, or (c) liberating plant food substances from soil compounds, the use of ground limestone has proved most economical.

In the Fertilizers and Lime experiment at Kentville, N.S., the pronounced influence of ground limestone, alone or in conjunction with manure and fertilizers, has been demonstrated.

Two corresponding series of plots, variously fertilized, were included in the liming experiments, one series being treated to an application of ground limestone, at the rate of 2 tons per acre, while the other series was unlimed.

In the year 1919 two three-crop rotations, consisting of potatoes, grain, clover hay, had been concluded, and the data for the six-year period are given in Table No. 22. The ground limestone was applied in the fall prior to the commencement of each rotation, the fertilizers in the following spring. At the conclusion of the first rotation, in the fall of 1916, the whole area received manure at the rate of 15 tons per acre. The value of the manure is reflected plainly in the relatively large yields from all crops in the second rotation.

TABLE 22.—INFLUENCE OF GROUND LIMESTONE AT KENTVILLE, N.S.

Treatment	Yields per Acre			
	Potatoes 1914	Oats 1915		Hay 1916
		Grain	Straw	
	bush.	bush.	lbs.	lbs.
<i>First Rotation (1914-15)</i>				
Neither lime nor fertilizers.....	55.9	30.4	1,615	720
Lime alone.....	67.6	32.8	1,675	1,110
Fertilizers alone.....	76.2	31.7	1,818	660
Fertilizers and lime.....	86.8	38.4	2,198	1,494
	Potatoes 1917	Wheat 1918		Hay 1918
		Grain	Straw	
	bush.	bush.	lbs.	lbs.
<i>Second Rotation (1917-19)</i>				
Manure alone.....	251.8	19.5	1,980	2,640
Manure and lime.....	313.4	29.8	2,260	4,090
Manure and fertilizers.....	292.4	23.7	1,996	3,126
Manure, fertilizers and lime.....	329.3	30.2	2,626	4,926

In both rotations the addition of ground limestone increased the yields substantially.

In the second rotation the fertility contributed by the manure permitted the combination of manure and lime to outyield the combination of manure and fertilizers. However, the highest yields in both rotations were obtained by the combined use of fertilizers and lime. It should be borne in mind that the fertilizer applications in this experiment were light, not exceeding 550 pounds per acre for each three-year period.

Lest any should be led to consider the results from liming at Kentville as representative of experience in general, it must be admitted that the soil at Kentville has responded to liming in a degree which is undoubtedly exceptional.

GROUND LIMESTONE AND BURNT LIME COMPARED AT CAP ROUGE

This experiment was carried out at the Experimental Station, Cap Rouge, Que., on a clay loam soil of more than average fertility. The object of the experiment was to ascertain the relative influence of lime in the forms of ground limestone and burnt lime, applied with and without barnyard manure.

The applications of the manure and the lime compounds were made in preparation for a crop of oats (in 1916) seeded down with clover and timothy, the observations being continued on the clover hay crop of the second (1917) and the timothy hay crop of the third year (1918).

The check plots and manure alone plots were in duplicate, the others in quadruplicate. The burnt lime was applied at the rate of 4,200 pounds per acre, the ground limestone at the rate of 7,500 pounds per acre, the same amount of lime per acre being furnished in each form.

The influence of the manurial and liming treatments may be traced in the yields of the three crops, as recorded in Table 23.

TABLE 23.—MANURE AND LIME EXPERIMENT AT CAP ROUGE, QUE. (1916-1918)

Plot No.	Manure	Treatment per acre		Yields per acre			
		Ground Lime-stone	Burnt Lime	Oats (1916)		Clover (1917)	Timothy (1918)
				Grain	Straw		
	tons	lbs.	lbs.	bush.	lbs.	lbs.	lbs.
1.....				46.5	3,680	3,460	4,760
2.....	15			45.9	4,400	5,140	6,980
3.....			4,200	50.6	4,220	5,380	6,370
4.....	15		4,200	59.4	4,830	6,670	7,160
5.....		7,500		46.5	3,730	5,070	5,490
6.....	15	7,500		49.4	5,320	6,230	7,570

While manure alone (plot 2), as was to be expected, produced no increase in the yield of grain, its influence on the yields of straw and of hay is pronounced. Still more substantial gains have followed its use with lime in both forms.

Burnt lime alone (3) has been throughout somewhat more effective than ground limestone alone (5). But with manure (6) ground limestone gives a better account of itself, producing more straw (though considerably less grain) in the first year and more timothy hay in the third year than the corresponding burnt lime plot. Comparison of the yields from the check (1) with those from plot 5 shows no gain from the use of ground limestone alone in the first year; but the increases from the latter are quite marked in each of the two succeeding years. The marked beneficial influence of lime on clover is characteristic. The earlier and more pronounced influence of burnt lime, as compared with that of ground limestone, agrees with general experience in the use of these materials in comparative tests.

LIME IN VARIOUS FORMS AT KAPUSKASING

On a silty clay soil, manured in the fall of 1919, at the Experimental Station, Kapuskasing, Ont., three sources of lime—(a) burnt lime, (b) slaked lime and (c) ground limestone—were compared in an experiment carried out in duplicate, the crops being potatoes (1920) and barley (1921). The rates of application were 3,000 pounds of burnt lime, 4,500 pounds of slaked lime and 6,000 pounds of ground limestone per acre, approximately the same quantity of actual lime being furnished in each form.

In a subsection of Table 24 the results following the use of 1,000 pounds of burnt lime in conjunction with fertilizers are shown.

TABLE 24.—SOURCES OF LIME EXPERIMENT AT KAPUSKASING (1920-21)

Plot No.	Lime and Fertilizer Treatment per Acre					Yields per Acre	
	Burnt Lime	Slaked Lime	Ground Lime-stone	Nitrate of Soda	Super-phosphate	Potatoes (1920)	Barley (1921)
	lbs.	lbs.	lbs.	lbs.	lbs.	bush.	bush.
5.....	Check					152.5	37.2
6.....	3,000					151.1	40.3
7.....		4,500				150.1	40.6
8.....			6,000			170.8	39.6
28.....	Check					85.0	29.3
30.....				100	400	146.0	33.2
34.....	1,000			100	400	164.0	31.8

The data in Table 24 are of a very indefinite nature. Of the three forms of lime, only ground limestone showed an increase in the yields of potatoes, the others being practically on a level with the check.

In the barley crop of the second year all three limed plots yield uniformly and show a measurable, though not large, increase over the yield from the check plot.

In the subsection of Table 24 burnt lime (1,000 pounds per acre) added to the nitro-phosphatic fertilizer (plot 34) was credited with a notable increase in yield of potatoes, but the advantage disappears in the barley crop. No doubt, the drought of 1921 impeded the normal functions of these substances in the soil and rendered the data somewhat obscure. The chief influence of the liming would, however, be looked for in the clover crop of 1922.

CHAPTER VI

FARMYARD MANURE AND GREEN MANURING

The practice of manuring represents the chief means of maintaining or increasing the supply of humus in the soil; this is one of the most important functions of manure and may prove frequently of greater importance than its fertilizing properties. As explained in Chapter 1, humus is the natural storehouse of nitrogen in the soil.

Cultivation of the soil promotes the oxidation and decomposition of the organic matter; consequently the more thorough and frequent the cultivation, the more rapid will be the depletion of the humus, and the greater the need for its replenishment.

NATURE AND COMPOSITION OF MANURE

No farm product is so variable as manure, the composition and value of which depend on a great many factors. Among these are the kind, age, function and food of the animal producing it, the quantity and nature of the litter employed, and, last but not least, the care taken in its production and preservation.

The analysis of a large number of samples of fresh horse and cow manure, from animals well fed and bedded with sufficient straw to hold all the liquid excreta, gives the following average figures per ton: Nitrogen 10 pounds, phosphoric acid 5 pounds, potash 10 pounds.

The following table states in approximate terms the relative proportions of solid (dung) and liquid (urine) excreta and bedding found in fairly well made manures of the more common farm animals. It gives the amounts of nitrogen, phosphoric acid and potash in these components, the data expressing percentages and pounds per ton:—

TABLE 25.—APPROXIMATE AVERAGE COMPOSITION OF MANURES (FRESH) FROM VARIOUS ANIMALS

Kind of Animal	Relative Proportions of Solid Excrement, Liquid Excrement and Bedding in Manure	Pounds per Ton	Nitrogen		Phosphoric Acid		Potash	
			p.c.	lbs.	p.c.	lbs.	p.c.	lbs.
Horse.....	Solid excrement.....	1,200	0.55	6.60	0.30	3.60	0.40	4.80
	Liquid " (urine).....	300	1.35	4.05	trace		1.25	3.75
	Bedding material.....	500	0.50	2.50	0.15	0.75	0.60	3.00
	Total mixture.....	2,000	0.66	13.15	0.22	4.35	0.58	11.55
Cow.....	Solid excrement.....	1,260	0.40	5.04	0.20	2.52	0.10	1.26
	Liquid " (urine).....	540	1.00	5.40	trace		1.35	7.29
	Bedding material.....	200	0.50	1.00	0.15	0.30	0.60	1.20
	Total mixture.....	2,000	0.57	11.44	0.14	2.82	0.49	9.75
Pig.....	Solid excrement.....	990	0.55	5.44	0.50	4.95	0.40	3.96
	Liquid " (urine).....	660	0.40	2.64	0.10	0.66	0.45	2.97
	Bedding material.....	350	0.50	1.75	0.15	0.42	0.60	2.10
	Total mixture.....	2,000	0.49	9.83	0.30	6.03	0.45	9.03
Sheep.....	Solid excrement.....	1,206	0.75	9.04	0.50	6.03	0.45	5.43
	Liquid " (urine).....	594	1.35	8.02	0.05	0.30	2.10	12.47
	Bedding material.....	200	0.50	1.00	0.15	0.30	0.60	1.20
	Total mixture.....	2,000	0.90	18.06	0.33	6.63	0.95	19.10
Poultry....	Solid excrement.....	1,900	1.00	19.00	0.80	15.20	0.40	7.60
	Bedding material.....	100	0.50	0.50	0.15	0.15	0.60	0.60
	Total mixture.....	2,000	0.97	19.50	0.77	15.35	0.41	8.20

A study of this table will reveal many important facts regarding manures; we desire here merely to emphasize one or two of the more valuable lessons that may be drawn from the data: First, that the liquid portion (urine) is much richer in nitrogen and potash than the solid excreta (dung), weight for weight. Second, more than one-half of the nitrogen and at least three-fourths of the potash excreted by the cow—the chief manure-producing farm animal—are to be found in the urine. The fact that these constituents are present in the urine in a soluble and readily available form adds greatly to their value. Pound for pound, nitrogen and potash in the liquid portion of manure are worth much more than those in the solid excreta.

LOSSES FROM MANURE

Losses from manure occur chiefly through fermentation and leaching. If piled in a loose heap, fermentation (due to the free access of oxygen) is rapid and serious loss of nitrogen, in the form of gases, results. Horse manure, being of looser texture and containing a larger proportion of undigested food, ferments more readily than cow manure. To reduce the danger of excessive fermentation, *the manure heap ought to be kept firmly packed and reasonably moist.*

Loss through leaching occurs when the manure heap is exposed to the action of heavy rains, or, if purchased from stockyards or livery stables, when the water hose is turned on it, after it has been loaded on the railway cars.

When we consider that more than one-half the nitrogen and at least three-fourths of the potash of manure is contained in the liquid portion (urine) the seriousness of loss by leaching will be readily appreciated.

Moreover, the nitrogen in the solid excrement, which has resisted the processes of digestion, is in an insoluble form and becomes only slowly available in the soil, whereas the constituents of fertility in the liquid, being already in solution, are almost immediately available.

THE INFLUENCE OF MANURE IN THE SOIL

The various beneficial influences which manure exerts may be stated as *chemical*, *physical* and *biological*.

CHEMICAL INFLUENCES OF MANURE

These are due to the amounts of nitrogen, phosphoric acid and potash present in the manure and which are liberated in the subsequent decomposition of the manure within the soil in forms assimilable by crops.

Were its value dependent alone on its chemical properties, this could be determined in the same manner as that of the ordinary commercial fertilizer, by finding the amounts of nitrogen, phosphoric acid and potash present and assigning to each a certain price per pound. Such a valuation, however, would disregard other, and perhaps equally, important properties of manure.

PHYSICAL INFLUENCES OF MANURE

Manure improves the physical character of both "heavy" and "light" soils, rendering the former more porous and friable and thus assisting aeration and drainage and in many other ways creating conditions more favourable for the development of the plant's root system.

A light sandy soil is rendered more compact by manure and its water-holding capacity thereby vastly increased.

Undoubtedly, the decomposition of the manure in the soil (a process of fermentation) liberates a considerable amount of heat, and thus it is that during the early weeks of spring, germination and the growth of the young plant will be encouraged on the manured land.

By liberal manuring a light sandy soil may be gradually converted into a productive loam and the darker colour which manure imparts will increase its heat-absorbing capacity.

BIOLOGICAL INFLUENCES OF MANURE

Manure not only furnishes the essential medium (humus) for the development of soil bacteria, myriads of which, in every fertile soil, are actively engaged in breaking down organic matter and releasing therefrom the elements of fertility in forms which can be assimilated by plants, but is itself a source of these useful bacteria. This fact, doubtless, in a great measure explains the beneficial effect of manure noted frequently on peat and muck soils. This type of soil although naturally composed largely of organic matter is often, owing to excessive acidity or other unfavourable conditions, insufficiently supplied with bacterial life.

INFLUENCE OF LITTER ON QUALITY OF MANURE

Straw is the bedding material almost universally used on the farm. It will absorb from two to three times its weight of liquid. If the supply is scanty, it will pay to cut all the straw used as litter, for finely cut it will absorb about three times as much liquid as uncut.

Dry sawdust and fine shavings can be recommended as clean and satisfactory bedding materials. Their absorptive capacity according to fineness and dryness is from two to four times that of ordinary straw.

Peat moss, commonly known as moss-litter (*sphagnum*) makes admirable bedding; it is soft and absorbent. It will absorb about ten times its own weight of liquid and possesses the further advantage of being able to retain any ammonia that may arise from the fermentation of the manure in the stable or outside.

Muck and peat when air-dried make excellent absorbents. They are being used as such to good effect on many Canadian farms. Deposits of these materials are of no uncommon occurrence in many parts of the Dominion and their value in this connection is fairly well known. Digging and piling are all that is necessary. Their use generally is supplemental to the bedding proper, being found more especially valuable in the gutter behind the cattle, and in and about the farm buildings where there may be liquid manure or drainage to absorb. This employment of muck can be strongly advised, since thereby not only may a saving of much liquid plant food be effected at little cost, but the bulk and value of the resulting manure will be very considerably increased by the organic matter and nitrogen of this naturally-occurring fertilizer.

THE APPLICATION OF MANURE

In so far as it may be practicable the manure should be drawn daily, fresh and direct, from the barn and stable to the land. For this purpose, as long as the condition of the soil permits and there is little or no snow, the manure-spreader (into which the manure from the carrier has been directly dumped) may be used. This practice means not only a great economy in labour, but the prevention of losses in plant food and humus-forming material that inevitably follow the accumulation of manure in the yard or piling in the field. It means also an equable and uniform distribution on the land—a matter of no small importance.

When the snow lies deep upon the ground, the manure may still be drawn to the fields—daily if possible—but instead of spreading it should be piled in small heaps of 200 to 400 pounds each. Fifty heaps of 400 pounds or one hundred heaps of 200 pounds each to the acre would mean an application of 10 tons.

With the advance of spring and the disappearance of the snow the piles of manure, now possible elevated a foot or more on a foundation of snow, are turned over and, when free from frost, scattered.

The advice given here as to the winter application of manure is based on the results of experimental work conducted chiefly at the Central Experimental Farm, Ottawa. These experiments proved:—

1. That manure left in a loose pile in the yard suffered very considerable losses, chiefly through the leaching away of soluble nitrogen and potash compounds, but

partly through fermentation (heating) and consequent destruction of organic matter with its nitrogen. In the course of a few weeks these losses may amount to one-third or more of the initial value of the manure.

2. That manure in large heaps or piles—whether in yard or field—heated rapidly, even in the coldest weather. In the course of three months—January to March—manure so piled lost, chiefly through excessive fermentation, 60 per cent of its original organic matter and nearly 30 per cent of its nitrogen.

3. That heaps of 400 pounds each, put out on the fields fresh from the barn and stable (mixed manure) showed no sign of heating throughout the experiment, January to March. For the greater part of the period these small heaps were frozen through and careful analysis made immediately before scattering them in the spring showed that while frozen there had been absolutely no loss, either in plant food constituents or organic matter.

GREEN MANURING

The growing and ploughing-in of a cover-crop furnishes a valuable means of supplementing the manure supply where the latter is scarce—an expedient of which advantage is taken more fully by the orchardist than by the ordinary agriculturist.

Legumes, such as clover and vetches, owe their popularity as cover-crops to the peculiar faculty, common to all plants of that family (*Leguminosae*) of deriving their nitrogen supply from the soil atmosphere by the aid of special bacteria which live in nodules or tubercles on their roots. Where its practice is possible, green-manuring with legumes commends itself as a means of enriching the soil in humus, as well as of supplying a large amount of valuable nitrogen, the most expensive ingredient in commercial fertilizers.

Investigations by the Division of Chemistry revealed the fact that a vigorous crop of clover will contain, in its foliage and roots, approximately, per acre—

100 to 150 pounds of nitrogen.

30 to 45 pounds of phosphoric acid.

85 to 115 pounds of potash.

A single crop of clover turned under would, thus, furnish the soil with an amount of nitrogen no less than would be supplied in 10 tons of manure per acre. The greater part of the nitrogen in the clover crop, having been derived from the air, is a distinct addition to the soil.

The amounts of phosphoric acid, potash and lime in the clover have, it is true, been derived entirely from the soil, but largely from depths beyond the reach of the roots of ordinary crops.

Because of difficulties experienced sometimes in obtaining a catch of clover, or where the cost of the clover seed may be deemed prohibitive, non-leguminous crops such as buckwheat and rye may be employed as green-manure crops.

In the orchards of the Annapolis Valley in Nova Scotia, clover, once the only cover-crop employed there, has, within the past decade, given place to buckwheat. The functions fulfilled by the use of the green-manure or cover-crop in the orchard are, however, somewhat dissimilar to those regarded chiefly in ordinary farm practice.

The modern apple grower has come to realize that only immediately available nitrogen, as furnished in nitrate of soda, avails to promote fruit-spur growth in the early spring season, and he does not desire excess of available nitrogen in the soil in the latter part of the season.

As compared with clover, the growth of buckwheat results in a lesser accumulation of nitrogen, and buckwheat serves admirably the purpose of withdrawing moisture from the soil at a time when the maturing of the wood is desirable, in order that the trees may the better withstand the winter frosts.

Many poor soils for which barnyard manure is unprocurable could doubtless be rendered vastly more productive by the growth and ploughing in of a crop such as buckwheat or rye.

Whatever the nature of the cover crop—clover, vetch, buckwheat, rye or rape—it should be turned under, preferably when full vegetative development has been attained but before ripening has rendered the stems woody and more resistant to decay.

IMPORTANCE OF HUMUS

The chief object to be attained by the use of barnyard manure or green-manures is the enrichment of the soil in humus, the importance of which, though referred to already, may be opportunely reiterated here.

We find that all our virgin soils of extraordinary richness and fertility are well supplied with vegetable (organic) matter, humus-forming material; and that soils exhausted by cropping and irrational systems of farming have had this material dissipated or destroyed. In addition to its value for increasing the water-holding capacity of a soil and otherwise improving its tilth, humus is important because it is the storehouse of nitrogen. Nitrogen is a valuable element of plant food, not merely because it is essential to the life of the plant, but because it is a very expensive form of plant food when we have to buy it for fertilizing purposes. When the humus is burned out of the soil by irrational methods of farming the nitrogen goes with it, for humus is nature's guardian of this important element. We have, therefore, to consider the humus content of the soil as indicating in a very large measure its relative fertility. The maintenance and, if possible, the increase of organic matter (humus forming material) should never be lost sight of in any scheme of fertilizing which may be adopted.

CHAPTER VII

FERTILIZER MATERIALS, THEIR ORIGIN, NATURE AND USES

THE ELEMENTS OF FERTILITY

Of the ten or twelve elements of plant food derived from the soil, *the available supply* of but three tends to become deficient for crop requirements, under normal conditions.

These are nitrogen, phosphoric acid (or phosphorus) and potash (or potassium).

Assuming that the average soil of the older farm areas in Eastern Canada contains in the surface, to a depth of nine inches, 0.15 per cent of nitrogen, 0.15 per cent of phosphoric acid and 0.30 per cent of potash, what amounts, per acre, of each element would these percentages represent?

The weight of soil covering one acre to a depth of nine inches is estimated at between two million and three million pounds. Taking two and one-half million pounds as the basis of our calculations, we find that the percentages of the elements noted would represent 3,750 pounds of nitrogen, 3,750 pounds of phosphoric acid and 7,500 pounds of potash per acre.

EXHAUSTION OF SOIL FERTILITY BY CROPPING

A 20-bushel crop of wheat (grain) removes from the soil about 24 pounds of nitrogen, 10 pounds of phosphoric acid and 6 pounds of potash. A 200-bushel crop of potatoes (tubers) removes about 42 pounds of nitrogen, 18 pounds of phosphoric acid and 60 pounds of potash. If we take the mean of these figures for wheat and potatoes, and assume that the average amounts represent the normal draft made by the growth of crops on the three plant food substances, we might estimate that cropping results in an annual loss to the soil of 33 pounds of nitrogen, 14 pounds of phosphoric acid and 33 pounds of potash.

Further assuming for this argument that cropping represents the only drain on soil fertility and that no restoration of fertility takes place, how long might productiveness be maintained?

According to our estimate of the total amounts of plant food present and the rate at which these are removed by crop growth, the nitrogen would be exhausted in 113 years, the phosphoric acid in 268 years and the potash in 227 years.

While these figures must be considered as purely conjectural, they serve to emphasize the fundamental truth upon which they are based, viz.: that continued cropping without a concomitant return of plant food must result in loss of soil fertility.

HOW PRODUCTIVENESS MAY BE LIMITED BY THE NITROGEN CONTENT OF SOILS

The nitrogen of soils exists largely in the organic matter, and, through the decomposition of the latter, is liberated gradually for crop use. The organic matter is limited chiefly to the upper soil, whereas the amounts of phosphoric acid and potash show less rapid diminution with increasing depth. Therefore, for deep-rooted crops the total quantities of phosphoric acid and potash that are within reach of the plant roots may be considerably greater than as shown in the foregoing calculation.

When a soil becomes "run-out" and unproductive, this condition is due, in the majority of cases, to lack of sufficient organic matter and nitrogen. Nitrogen proves most frequently the factor limiting productiveness, and *the inherent fertility of the average soil may be measured by its nitrogen content.*

Through a wise provision of nature the capital stock of fertility in the soil may be drawn on only very gradually by crops. The conversion of the plant food substances into forms which can be assimilated by plants proceeds very slowly. It has been estimated that of the total nitrogen in the soil not more than a one-hundredth part is present, at any one time, as nitrate, the only form in which nitrogen is assimilable by plants.

Accordingly, under summer conditions most favourable to nitrification, there would be present in the average soil not more than 40 pounds of nitrate nitrogen per acre. This fact enables one to understand why nitrate of soda, applied at the modest rate of 100 pounds per acre and supplying only $15\frac{1}{2}$ pounds of nitrate nitrogen to the soil of that area, may produce such marked results on crop growth. This influence is likely to be more particularly noticeable following the application of nitrate of soda in early spring when soils are practically devoid of nitrate nitrogen, for even the richest soil must await the warmth on which, as well as other factors, the process of nitrification is dependent.

PRIMARY FUNCTIONS OF THE ESSENTIAL ELEMENTS OF FERTILITY

Nitrogen promotes more particularly the growth of stem and leaf and is demanded largely during the period of active vegetation. The bulk or size of the crop is regulated in a great measure by the supply of available nitrogen, so, if nitrogen in suitable form be lacking, crops cannot avail themselves fully of the phosphoric acid and potash present in the soil.

Phosphoric Acid influences root development in the early stages and seed or fruit formation in the later stages of growth. Its importance for turnips and grain crops may thus be explained. Phosphoric acid promotes fruitfulness and, in some measure, early ripening, and is therefore important for all seed-bearing plants.

Potash is essential to the formation of carbohydrates which comprise the starches of potatoes, grains, etc., the sugar of fruits and vegetables and the fibrous matter of plants.

THEORIES RESPECTING PLANT FOOD REQUIREMENTS

Some of the earlier investigators in the field of agricultural chemistry believed that the kind and quantity of mineral matter found in the plant ash furnished an accurate indication of the mineral plant food requirements in each specified case and supplied a reliable basis for determining the fertilizer applications to the several crops. Subsequent investigations, however, proved the fallacy of this theory, and consequently it has been abandoned as a guide to rational fertilizing.

Further, in respect to their fertilizer or food requirements, it has been shown that crops vary in their power of assimilation. It does not necessarily follow that the presence, of, say, potash in large quantities in the plant composition indicates the need of a highly potassic fertilizer. For instance, a 700-bushel (per acre) crop of turnips (roots) contains three times as much potash as a 200-bushel crop of potatoes (tubers) and yet turnips, if liberally manured, rarely derive benefit from a potash fertilizer, whereas potash is the fertilizer ingredient to which potatoes particularly respond.

The amounts of the plant food substances contained in certain of the more important farm crops are given in the following table:—

TABLE 26—PLANT FOOD CONSTITUENTS IN FARM CROPS

Yield per Acre (approximate average)	Nitrogen	Phosphoric Acid	Potash
	lbs.	lbs.	lbs.
Wheat (grain) 25 bushels.....	30	12	7
Oats (grain) 50 bushels.....	34	14	10
Barley (grain) 35 bushels.....	30	13	9
Timothy Hay, 2 tons.....	60	40	90
Clover Hay, 2 tons.....	84	20	80
Corn (for ensilage) 15 tons.....	66	33	120
Turnips (roots) 15 tons.....	54	30	115
Mangels (roots) 15 tons.....	57	27	115
Sugar Beets (roots) 15 tons.....	63	24	110
Carrots (roots) 12 tons.....	48	12	62
Potatoes (tubers) 200 bushels.....	42	18	60
Apples (trees in full bearing), fruit, leaves and wood.....	65	15	90

Reference has been made already to the fact that the quantity of each plant food element removed by the crop does not furnish us with an accurate estimate of its fertilizer requirements. In this connection, however, it should be observed that a crop of weak feeding or foraging power, following one which has made a heavy draft on the soil's available supply of a certain element, may require a more liberal supply of that element in the manure or fertilizer than would have been necessary had it followed a less "exhaustive" crop. Recognition of this feature would require that sometimes in determining the quality and quantity of a fertilizer application the nature of the crop grown in the past year, as well as the normal anticipated requirements of the crop to be grown in the present year, would have to be considered.

THE PLACE OF FERTILIZERS IN AGRICULTURE

Fertilizers, as a means of restoring to the soil the plant food substances removed by the growth of crops, are supplemental to farmyard manure.

Farmyard manure is a fertilizer, though, in the soil, its physical and biological influences may prove of even greater value than its chemical or fertilizing effect.

Fertilizers are materials that furnish in available forms one or more of the three so-called essential elements of fertility: nitrogen, phosphoric acid and potash. A fertilizer that supplies all three is known as a "complete" fertilizer.

To furnish plant food in soluble forms, readily available to the growing crop, is the primary function of a fertilizer.

Every fertile soil contains in itself large stores of the essential plant food substances, from which, under conditions, favourable to the necessary chemical and bacterial processes, supplies are liberated gradually and transformed for crop use. Under ordinary conditions these soil processes progress so slowly that the liberation of plant food substances may fail, during the period of most active growth, to satisfy fully or keep pace with the crop's demands for soluble nutriment.

One of the most important soil processes dependent on bacterial agency is that of nitrification, which involves the decomposition of the humus, the liberation therefrom of nitrogen or ammonia and, by further steps, the production of a nitrate, the highly oxidised form in which plants assimilate nitrogen.

SOME SOURCES OF FERTILIZER MATERIALS

The products of *saline* and *mineral deposits*, found in different parts of the world, represent a very large proportion of the total fertilizer consumption.

From *Saline Deposits*, nitrate of soda is produced in Chile, South America, and potash salts in Central Germany and the French province of Alsace.

From *Mineral Deposits*, in Florida, Tennessee and elsewhere, we obtain phosphate rock which, when ground and treated with sulphuric acid, yields superphosphate.

From *Organic Deposits* were obtained formerly the once-popular guanos, rich in nitrogen and phosphoric acid. These valuable deposits consisting, supposedly, of the excreta and decaying remains of sea-fowl, soon became exhausted. The natural guanos now obtainable are largely phosphatic and contain little or no nitrogen.

From the *Atmosphere*, the nitrogen of cyanamide and nitrate of lime is derived through the medium of electrical energy.

Industrial By-products.—In this category we have:—

- (a) **SULPHATE OF AMMONIA**, as a source of nitrogen next in importance to nitrate of soda, which derives its nitrogen from coal and is a by-product of smelters, gas and coke works.
- (b) **BASIC SLAG**, a popular alkaline phosphatic fertilizer and by-product in the manufacture of steel by either the basic Bessemer or open-hearth process.
- (c) **DRIED BLOOD, TANKAGE AND BONE MEAL**, chief among the organic materials now employed as fertilizers and all by-products of the abattoir or meat-packing establishment.

COMMERCIAL FERTILIZERS

Commercial fertilizers, as we have seen, may be chemical compounds, such as nitrate of soda, superphosphate, etc., or may be of organic origin, such as bone meal, dried blood, tankage, etc.

Frequently, the compounded fertilizer as manufactured and sold under brand or trade names consists of a mixture of both classes of materials.

The Dominion Fertilizers Act.—This Act provides for the registration of every fertilizer offered for sale as such in Canada. A registration number is given and this number serves as a means of identification, for the Act provides that the guarantee of analysis, together with the registration number of the fertilizer, shall be stencilled on each bag or other container or printed legibly on a tag attached durably thereto.

BRAND NAMES OF COMMERCIAL FERTILIZER MIXTURES

There are numerous—far too numerous—brands of ready-mixed fertilizers on the market, which contain varying percentages and proportions of nitrogen, phosphoric acid and potash. Many of these are described by the manufacturer as being specially adapted for the needs of certain crops. The farmer, however, should study the composition, not the name, of a fertilizer. Some fertilizer mixtures are called by attractive and often very pretentious names. But a name, especially if a misnomer, is a poor basis whereon to build the reputation of a fertilizer.

As showing the futility of relying on a brand name as an indication of the fertilizer's adaptation or value, let us examine two issued by one firm and registered for sale in Canada. Each is designated by name, as a *special potato fertilizer*, yet they differ widely in composition, as the following analyses show:—

	Nitrogen	Phosphoric Acid	Potash
	p.c.	p.c.	p.c.
Brand No. 1.....	4.11	9.00	7.00
Brand No. 2.....	0.82	9.00	2.00

Whereas No. 1 is a high grade fertilizer, No. 2 is very low grade and lacks the high percentages of nitrogen and potash, which should characterize a fertilizer for potatoes.

Brand No. 2 would contain an excessive amount of filler, for the plant food substances contained in one ton of the material could be furnished by 106 pounds of nitrate of soda, 1,125 pounds of 16 per cent superphosphate and 80 pounds of muriate of potash.

NITROGENOUS FERTILIZERS

NITRATE OF SODA (15 to 16 per cent of nitrogen) is the most popular and quickest acting nitrogenous fertilizer. Its nitrogen is not only soluble in water but, being in the nitrate form, is directly and immediately available to the growing crop. This quick action of nitrate of soda renders the material particularly suitable for use also as a supplemental top dressing to crops which may lack vigour and be in need of a stimulus.

Experiments have proved that the danger of loss of nitrate nitrogen by leaching has been greatly exaggerated, at least in so far as this applies to that furnished in nitrate of soda. Little loss by leaching occurs during late spring and summer. Evaporation and the consequent upward trend of the soil moisture tend to prevent this. The greatest loss by leaching occurs in the fall, and the nitrates then present in the soil moisture are chiefly those derived by nitrification from the humus.

SULPHATE OF AMMONIA (20 per cent of nitrogen) in its action is slower than nitrate of soda, for, although its nitrogen is all soluble in water, it does not become available for absorption by plants until converted by nitrification into the nitrate form. However, under favourable conditions, this takes place fairly rapidly—the more so as soil warmth increases.

The continued and exclusive use of sulphate of ammonia as a source of nitrogen tends to render the soil distinctly acid. Its use should be restricted to soils plentifully supplied with lime. The results of certain experiments in Canada have indicated that a mixture of nitrate of soda and sulphate of ammonia may sometimes produce results superior to those obtained from the use of either of these materials alone.

DRIED BLOOD—an abattoir by-product—is prepared in two grades: red dried blood (12 to 16 per cent of nitrogen), and black dried blood (6 to 12 per cent of nitrogen and 3 to 4 per cent of phosphoric acid).

The former is a rather scarce commodity and its cost prohibits its extensive employment as a fertilizer. It is prepared by drying the blood with hot water at low temperatures.

Black dried blood is dried at higher temperatures. It is a more or less impure product and is more variable in composition than the red. It is employed largely as a source of nitrogen in ready mixed fertilizers of the higher grades.

Of all sources of organic nitrogen dried blood is undoubtedly the most valuable. It is best adapted to soils which are warm, moist and well aerated and under these favourable conditions the rate of the liberation of its nitrogen may be almost equal to that in sulphate of ammonia.

TANKAGE—also an abattoir by-product—is produced in several grades which vary widely in their composition according to the proportions of meat, bone, etc., employed in their preparation.

The two principal grades are: concentrated tankage (8 to 12 per cent of nitrogen and 2 to 5 per cent of phosphoric acid) and crushed tankage (5 to 8 per cent of nitrogen and 5 to 15 per cent of phosphoric acid).

In the manufacture of concentrated tankage the animal refuse is submitted to a cooking process and the fat, as far as practicable, removed. The tankage is then evaporated to dryness. Most of the up-to-date abattoirs now subject the material to further treatment with naphtha or gasoline as a solvent, with the object of reducing the percentage of fat to a minimum.

Crushed tankage is less valuable and more variable in composition than the concentrated grade. In both the nitrogen is of much slower availability than that in dried blood. They are therefore adapted more particularly to crops having a long season of growth.

Tankage, in various forms, enters largely into the composition of commercial fertilizer mixtures.

There are numerous other abattoir by-products, such as hoof and horn meal, wool and hair waste. In these the nitrogen may be rendered available through treatment of the materials with acid.

It is particularly desirable, in purchasing tankage, to carefully examine the statement of analysis, as this material varies widely in its nitrogen and phosphoric acid content.

CYANAMIDE AND NITRATE OF LIME—These compounds are obtained by the fixation of atmospheric nitrogen through electrical energy.

Of late years considerable progress has been made in the preparation of nitrogenous fertilizers the nitrogen of which is derived from the atmosphere. In these processes electrical energy generated by water-power is employed, and, at very high temperatures, oxides of nitrogen are induced to combine with lime (as in nitrate of lime) or with lime and carbon (as in cyanamide).

CYANAMIDE (14 to 20 per cent of nitrogen) when applied to the soil, gradually undergoes conversion therein to ammonia which is subsequently converted into a nitrate of lime and, in this form, taken up by plants. In this final conversion into nitrate cyanamide is similar to sulphate of ammonia.

It has been observed that cyanamide may injuriously affect germinating seed and, for this reason, should be applied from one to two weeks prior to seeding time. It is in the form of a very fine powder and is rather disagreeable to apply. If mixed with dry superphosphate the objectionable features in its application may be largely avoided. In order to obviate loss of nitrogen, the mixture should be applied immediately.

Owing to the tendency of cyanamide to rapidly absorb moisture when exposed to the atmosphere, it should be carefully stored in a dry place.

NITRATE OF LIME OF NORWEGIAN SALTPETRE (12 to 13 per cent of nitrogen) like nitrate of soda, contains its nitrogen in the immediately available nitrate form.

Nitrate of lime is, however, so deliquescent that its exposure to the air results in rapid absorption of moisture by the material and its ultimate hardening like cement. Until these objectionable features have been overcome, nitrate of lime is not likely to become popular as a source of nitrogen.

PHOSPHATIC FERTILIZERS

Bones represent the oldest phosphatic fertilizer and are still employed largely in various forms.

BONE MEAL (20 to 25 per cent of phosphoric acid and 3 to 4 per cent of nitrogen) results from the grinding of the raw bone.

The phosphoric acid in bone meal, although not immediately available, is, by reason of the decomposition of the bone in the soil, liberated gradually in forms utilized by crops.

Bone meal is frequently styled a "lasting" manure from the fact that its decomposition is necessarily slow. It gives its best results on soils which are warm, moist and rather light and well aerated. It owes its popularity in green-house work, undoubtedly, to the presence of these ideal conditions of soil, moisture and temperature. It further seems probable that here the chief beneficial influence is frequently due to the nitrogen of the bone meal, which is rendered available gradually to the

plants at a rate favourable to their rational development, under green-house conditions.

STEAMED BONE FLOUR (28 to 30 per cent of phosphoric acid and about $1\frac{1}{2}$ per cent of nitrogen) results from the steaming or boiling of bone, under pressure, for the removal of the fat and the cartilage.

The loss of nitrogen in this process is to a very large degree compensated for by the higher percentage of phosphoric acid, the absence of fat which retards decomposition in the soil and the greater degree of fineness to which the material may be ground.

DISSOLVED BONES (BONE SUPERPHOSPHATE).—This material contains from 13 to 16 per cent of available phosphoric acid and from 1 to 2 per cent of nitrogen.

Sir John Bennet Lawes, founder of the world-famed Experiment Station at Rothamsted, England, instituted in the year 1834 experiments with bones as a fertilizer and found that by their treatment with sulphuric acid, part of the phosphoric acid in the bone was rendered soluble in water and therefore more readily available to plants. The name given to this product was "*superphosphate*". Later on, the discovery of the mineral (rock) phosphates furnished a new material which, treated in the same way, produced similar results, save, of course, that the product contained no nitrogen.

Dissolved bone or bone superphosphate is now rarely found on the market, but the term "*bone superphosphate*" is often erroneously applied to ordinary superphosphate.

ROCK PHOSPHATE; APATITE, FLOATS.—There occurs in certain parts of Canada a native phosphate of lime, known as apatite. This material can be used advantageously in the production of superphosphate (acid phosphate), but does not in the crude state—even when finely ground—furnish available phosphoric acid to growing crops, in appreciable amounts. For this reason it is not used directly as a fertilizer. Floats is the name of the untreated but very finely powdered phosphatic deposit found in several of the Southern States (Florida, Tennessee, South Carolina, etc.).

Although not directly soluble in water, it would appear that on soils rich in organic matter and also when applied associated closely with heavy applications of manure, the phosphoric acid of Floats is liberated very slowly in available forms.

SUPERPHOSPHATE OR ACID PHOSPHATE.—This is sold usually in two grades containing 14 and 16 per cent, respectively, of available phosphoric acid, but lower grades are not infrequently met with.

Superphosphate is the resultant product when raw phosphate rock is treated with sulphuric acid. By this process the greater part of the phosphoric acid of the rock phosphate is rendered soluble in water and, therefore, immediately available to plants. In addition to this water-soluble phosphoric acid, superphosphate, especially on long storage, contains a part of its phosphoric acid in a condition known as "citrate-soluble" (that is, soluble in a neutral solution of ammonium citrate). The "water-soluble" and the "citrate-soluble," known also as "reverted," together constitute the "available" phosphoric acid. All superphosphates will contain also a small, variable percentage of insoluble phosphoric acid (from the presence of phosphate rock that has not been acted upon in the process), but this is not considered in estimating the agricultural value of the product; the "available" (water soluble plus citrate-soluble) phosphoric acid present fixes the value of any particular brand of superphosphate.

Superphosphate is undoubtedly the most popular phosphatic fertilizer on the market to-day. The ready availability of its phosphoric acid enables it to exert its maximum beneficial influence during the first season. It is suitable for application to a large variety of soils, but more particularly valuable as a source of phosphoric acid for soils well supplied with lime. The sulphuric acid, used in the manufacture of superphosphate unites with the lime displaced to form sulphate of lime or gypsum of which ordinary superphosphate may contain 40 to 50 per cent.

"DOUBLE" and "TREBLE" SUPERPHOSPHATE (25 to 45 per cent of available phosphoric acid).—These, as their names imply, may contain double or treble the amount of available phosphoric acid present in ordinary superphosphate.

The process by which they are produced is an expensive one, and consequently these concentrated superphosphates are not often met with. But, where long haulage and high freight rates are encountered, they may yet become of considerable importance.

They contain little or no sulphate of lime or gypsum, the absence of which renders their drying out—subsequent to manufacture—more difficult than in the case of ordinary superphosphate.

BASIC SLAG OR THOMAS PHOSPHATE POWDER (10 to 18 per cent phosphoric acid) is a by-product in the manufacture of steel by the Bessemer or the open-hearth process. The open-hearth process is now most largely employed in steel-manufacture, and the basic slag by-product is lower in phosphoric acid than formerly.

The crude iron (pig-iron) contains a small amount of phosphorus, which would injure the quality of the resultant steel. This is removed by lining the "converters" with lime which absorbs the phosphoric acid, forming a basic phosphate. On removal from the converters this basic slag becomes a hard cinder which is ultimately reduced to a very fine powder by crushers and grinding mills. Since the availability of the phosphoric acid depends largely on the degree of fineness to which the material is reduced, 85 per cent of the sample should be capable of passing through a sieve having 100 wires to the linear inch. The degree of fineness should be stated in the guarantee.

Basic slag contains varying small proportions of free lime which, together with the lime in combination, frequently represents the equivalent of 40 per cent of lime. The basic or alkaline character of the slag doubtless accounts in a large measure for the marked beneficial effects produced by this fertilizer on sour soils, for which it is in consequence preferred to acid phosphate. Further, basic slag possesses a distinct value for ameliorating the texture of heavy clay loams, rendering them mellow and less plastic. Being slower than acid phosphate in yielding up its phosphoric acid, basic slag should be applied in the autumn or very early in spring, in order that its maximum influence may be exerted in the first season. For pastures, turnips, grain crops, clover and other legumes, basic slag has proved a valuable phosphatic fertilizer.

POTASSIC FERTILIZERS

European Potash Salts.—These have their origin in the extensive deposits of Central Germany and in the French province of Alsace and represent the world's chief source of potash. The products from both French and German mines and refineries are essentially the same, the highly concentrated muriate and sulphate of potash being the principal forms in which the potash is exported.

American Potash.—The exclusion of European potash during the war stimulated search for and exploitation of sources of potash on this continent. Of the industries created to meet the needs of the peculiar situation but few survived the resumption of trade in European potash. Excepting the potash salts (Trona potash) derived from brines in the state of Nebraska, no other sources of potash can be said to compete now with the salts imported from France and Germany.

MURIATE OF POTASH (48 to 52 per cent of potash) is the most popular source of potash for fertilizer purposes and is suitable for application to most crops.

SULPHATE OF POTASH (48 to 52 per cent of potash) is in most respects similar to muriate. It is preferred to muriate for tobacco, being free from chlorides, the presence of which tends to impair the quality of the tobacco leaf. For a similar reason sulphate of potash is sometimes preferred to muriate for the fertilizing of potatoes and sugar beets, though it is doubtful whether adequate grounds for the preference or prejudice exist.

CARBONATE OF POTASH (50 per cent of potash) is an exceedingly valuable and desirable potassic fertilizer and suitable in form for tobacco.

It is produced to a limited extent in Canada from the incineration of the mother-liquor by-product of beet sugar manufacture.

KAINIT (12½ per cent of potash) is a crude ground potash salt, a product of the European potash mines. It is not now used extensively in Canada.

WOOD ASHES.—The ashes of wood have long been recognized as a fertilizer of very considerable value; indeed their use in agriculture is historic. In all countries, including Canada, practising agriculture they have been highly prized, especially for clover, grapes and fruit trees and leafy crops generally, on sandy and light loam, and it was only with the advent of the German potash salts that their use fell off, though, of course, their production in decreasing quantities of later years, owing to the disappearance of our forests, has been an important factor in making it more and more difficult for the farmer in the older settled districts to obtain them. Their potash is present essentially in the form of a carbonate, probably the most acceptable form for use as a fertilizer. In good unleached, dry wood ashes there may be present from 4 to 6 per cent of potash, about 2 per cent of phosphoric acid and from 25 to 35 per cent of lime.

SEAWEED represents another and important source of potash. While essentially a potassic fertilizer, it contains also notable amounts of nitrogen and other elements of plant food, so that it might be termed a complete manure. Many varieties in the fresh condition have a composition very similar to that of good barnyard manure.

The manurial value of seaweed is greatly enhanced by its ready decomposition in the soil; it quickly decays, liberating its constituents in forms available for plant nutrition. It is quite unnecessary to compost it, though little loss would ensue if composted with muck or other vegetable matter which would absorb and hold the decomposition products, provided the heap is not exposed to heavy leaching rains.

Seaweed can be employed for all classes of crops, though it will be found most useful for potatoes, roots, vegetables and those with an abundance of foliage, since it is essentially a nitrogenous and potassic manure.

TABLE 27.—COMPOSITION OF THE PRINCIPAL FERTILIZER MATERIALS

Fertilizing Materials	Nitrogen	Phosphoric Acid		Potash
		Available	Total	
	p.c.	p.c.	p.c.	p.c.
Nitrogenous Fertilizers—				
Nitrate of soda.....	15-16			
Sulphate of ammonia.....	19-20½			
Cyanamide.....	14-20			
Nitrate of lime.....	12-13			
Dried blood (red).....	12-16			
Nitro-Phosphatic Fertilizers—				
Dried blood (black).....	6-12		3-4	
*Concentrated tankage.....	8-12		2-5	
**Crushed tankage.....	5-8		5-15	
Dried fish scrap.....	7-9		6-8	
Bone meal.....	3-4		20-25	
Steamed bone flour.....	1-2		26-30	
Dissolved bone.....	1-2	13-16	15-17	
Phosphatic Fertilizers—				
Ground phosphate rock.....			25-35	
Superphosphate (acid phosphate).....		14-16	14-20	
Double and Treble superphosphate.....		30-45	35-50	
Basic slag.....			10-18	
Potassic Fertilizers—				
Muriate of potash.....				48-52
Sulphate of potash.....				48-52
Kainit.....				12-13
Nitro-phospho-potassic Fertilizers—				
Tobacco stems.....	2-3		3-5	5-8
Phospho-potassic Fertilizers—				
Wood ashes (unleached).....			1½-2½	4-6

* Consisting chiefly of flesh offal.

** Contains varying proportions of bone.

CHAPTER VIII

LIME AND OTHER SOIL AMENDMENTS

QUICK LIME

Lime, known also as quicklime, burnt lime, caustic lime, stone lime, etc., is produced from the burning of limestone (carbonate of lime) with wood or coal. The burning may be performed either in a specially constructed kiln or by the simpler method of heap-burning. The intense heat decomposes the carbonate, carbonic acid gas being driven off and caustic or quicklime remaining.

SLAKED LIME

Slaked lime, known also as hydrated lime, results from the union of water with quick lime. The process of slaking, or adding water to the lime, is commonly practised by builders in the making of mortars, and is accompanied by the generation of a considerable amount of heat. The result is a whitish-grey or greyish-white (according to the quality of lime) powder having properties that are distinctly caustic and alkaline. The heap of lime in slaking swells to nearly double its original bulk and a bushel of freshly-slaked lime will weigh approximately 40 pounds, as compared with 70 pounds per bushel, which may be taken as the average weight of lime. The weight of lime, however, may vary between 60 and 100 pounds per bushel, according to its degree of purity and the thoroughness of burning. This fact furnishes an argument in favour of purchasing lime and lime compounds by weight rather than by measure.

Air-slaked lime results from the long exposure of quicklime to the air. The lime first absorbs moisture, being converted into the hydrate (slaked lime), which then takes up and combines with the carbonic acid gas of the atmosphere to form the carbonate. Slaked lime, therefore, is variable in composition; it may be essentially slaked lime with a small percentage of carbonate, or largely carbonate of lime with traces only of slaked lime, depending chiefly upon the duration of the exposure.

LIMESTONE, MARL

These are essentially carbonate of lime. Limestones are not all identical in composition; some contain notable amounts of carbonate of magnesium and are known as magnesian limestone or dolomite; others contain varying proportions of inert rock material. Hence the higher grades of limestone used in agriculture may be almost pure carbonate of lime, while the lower grades may contain less than three-fourths of their weight of carbonate.

Marls containing over 90 per cent of carbonate of lime are frequently found in Canada; others containing varying proportions of clay, sand or organic matter may show as low as 30 per cent of carbonate of lime. Chiefly by reason of the facility with which they may be reduced to a fine powder, marls constitute a very suitable form of carbonate of lime for use in agriculture.

THE AGRICULTURAL FUNCTIONS OF LIME AND ITS COMPOUNDS

The chief objects of applying lime or carbonate of lime are two: the neutralization of acidity and the improvement of tilth or mechanical conditions of soils.

ACIDITY OR SOURNESS

Lime and carbonate of lime combine with and neutralize the soil's acids and the excess used renders the soil slightly alkaline—a condition favourable to crop growth.

Wet, low-lying and ill-drained soils are especially apt to become sour. Soils consisting essentially of vegetable organic matter, as mucks and peat loams, are usually, though not invariably, sour. Many light upland soils are slightly acid, presumably by the washing out and leaching away of their original store of carbonate of lime or its withdrawal by many years of cropping.

In all soils in humid districts, but more especially in sandy and gravelly loams, there is a tendency for the lime compounds to disappear, partly through removal by crops but more particularly by their solution (in water containing carbonic acid) and passage into the strata below the root area.

METHOD OF TESTING FOR ACIDITY WITH LITMUS PAPER

The usual test for soil acidity is blue litmus paper, which may be purchased at any drug store. It should be kept in a clean, dry, preferably wide-mouthed well-corked bottle. When tearing or cutting off a strip of litmus paper for use, a pair of forceps or scissors should be used, as the paper is sensitive and the fingers may cause its reddening. The following test, if carefully carried out, is reliable:—

Take up, by means of a spade or trowel, a little of the surface soil from, say, half a dozen places on the area to be examined and mix well; do not handle the soil. Take a small quantity (a few ounces) of the sample, put it in a clean cup or tumbler, pour on a little boiled water and stir with a clean piece of stick or spoon until a pasty mass is obtained. Into this "mud" press, by means of a small stick or the back of a knife, a strip of blue litmus paper for about one-half to two-thirds of its length. If on drawing out the paper, at the end of fifteen minutes, the part in contact with the soil has turned red, then the soil is acid.

INFLUENCE OF LIME ON TILTH

The influence of lime and its compounds upon the tilth or texture of the soil is most marked in the case of clays, which it renders less sticky and cohesive when wet, and more friable and mellow when dry. On light soils—sandy and gravelly loams—lime and carbonate of lime exert a beneficial influence, their action being to cement slightly the soil particles, rendering the soils somewhat heavier and more compact in texture and, thus, less liable to dry out in seasons of drought.

CHEMICAL EFFECTS OF LIME COMPOUNDS

In addition to their beneficial effects already described, lime, as also carbonate and sulphate of lime, possesses in a considerable degree the power to decompose the insoluble potash compounds in the soil, the lime taking the place of the potash, which is liberated in a form assimilable by plants. *Thus the lime compounds may act as indirect potash fertilizers.* The effect is naturally most noticeable on clays and will most materially benefit clover and other leguminous crops which more particularly respond to potassic fertilizers.

INFLUENCE OF LIME ON THE BACTERIAL LIFE OF THE SOIL

The humus or semi-decayed organic matter in the soil is the main source and storehouse of nitrogen, the dominant and most costly element of plant food. Before this humus-nitrogen can be utilized by growing crops it must be oxidized and converted into nitrates. This process, known as nitrification, is the life work of certain vegetable micro-organisms or bacteria within the soil. In soils deficient in carbonate of lime, and especially in ill-drained, water-logged soils, the decay of the organic matter is accompanied by the development of certain organic acids, and thus the soil becomes sour. This acid condition of the soil is distinctly unfavourable to the life and development of the useful nitrifying organisms, for these can flourish only in a neutral, or slightly alkaline soil. Lime and carbonate of lime neutralize these acids.

making the soil a suitable medium for the growth of these bacteria and, further, furnish a base or alkali to combine with the nitric acid produced by them. The nitrate of lime so formed, is, no doubt, the immediate source of nitrogen supply of our field crops.

COMPARATIVE VALUES OF LIME COMPOUNDS

All forms of lime used in agriculture are not of equal value, especially for the correction of acidity. In acid-correcting power and in furnishing available lime, and considering the various forms on a basis of equal purity, 56 pounds of quicklime is the equivalent of 74 pounds of freshly-slaked lime and of 100 pounds of carbonate of lime, whether it be as marl or ground limestone. Air-slaker lime, for reasons already noted, may be partly hydrate and partly carbonate; its value will, therefore, be intermediate between that of freshly-slaked lime and the carbonate; that is, 56 pounds of quicklime will be equal to a weight of air-slaked lime between 74 and 100 pounds. Presenting these facts in tabular form we have:—

2,000 lbs. quicklime = 3,571 lbs. ground limestone and marl.

2,000 lbs. quicklime = 2,643 lbs. freshly-slaked lime.

If quicklime were worth \$7 per ton, ground limestone, equally free from impurities, would be worth \$4.10 per ton, and freshly-slaked lime, \$5.50 per ton. While the above comparison, as to equivalent weights and values, may serve in a general way, an analysis is necessary when the exact lime value of any particular sample or samples is desired.

IS LIME OR CARBONATE OF LIME PREFERABLE?

In settling this question the character of the soil and the desired rapidity of action should be considered.

On account of their influence in hastening the decomposition of the humus, quicklime and slaked lime are not so desirable or safe to use on light sandy and gravelly loams as are ground limestone and marl. If lime be applied to these soils it should be in small dressings (not more than 1,000 pounds per acre) and at long intervals. Carbonate of lime (limestone and marl) is much milder in its action and an excess can do little or no harm.

For heavy clays, or soils rich in organic matter, mucks and peaty loams, lime or slaked lime is to be preferred and may be applied in fairly large amounts—say 1½ to 2 tons per acre. These compounds are gradually converted into carbonate of lime within the soil, but being more vigorous and active from the outset and being in finer powder than ground limestone, they pass more readily into solution, thus allowing a more uniform distribution throughout the soil. As a result their influence in flocculating the clay particles and improving tilth will be more rapid. For the same reason the chemical action also of these forms is more vigorous than that of ground limestone and marl.

GYPSUM OR LAND PLASTER

Gypsum may be valuable agriculturally in furnishing lime for plant growth, as it is fairly soluble in water, but since in this form lime is combined with sulphuric acid and is present in neutral conditions it follows that *gypsum has no value for the treatment of sour or acid soils*. For this purpose it cannot take the place of quicklime, slaked lime, marl or ground limestone, which are essentially alkaline in character.

The two chief agricultural functions of land plaster are its property of flocculating clay and its effect or influence on the insoluble potash compounds, setting free this element in forms available for plant use. The first of these functions makes it valuable for the dressing of heavy clay loams, which it improves in tilth by rendering them less plastic, more open and friable; in a word, mellowed and more easily worked.

THE APPLICATION OF LIME COMPOUNDS

QUICKLIME.—In order to facilitate its uniform distribution over the soil, quicklime should be slaked. Place the lime in small heaps of about a bushel each at regular distances on the field to be treated. Pour a little water, about one-third the weight of the lime, so that the slaking may be gradual and a fine powder result, on each; cover the heap with an inch or two of moist soil and allow to remain for two or three weeks, when the lime will be thoroughly slaked and fall into a fine powder. Mix the slaked lime with a little soil and spread with a shovel, choosing preferably a damp day for the work.

Forty heaps of about 50 pounds or twenty-five heaps of 80 pounds each is an application of approximately one ton per acre.

SLAKED LIME.—This is in the form of a powder and may be most conveniently, pleasantly and uniformly spread by employing a lime spreader or fertilizer drill. It can, of course, be spread from a wagon box, but the operation is more or less disagreeable. If this method is adopted, the mixing of the slaked lime with a little fine soil is said to make the handling less unpleasant.

For these more caustic forms—quicklime and slaked lime—autumn is probably the best season for application, spreading on the ploughed land and immediately harrowing it in. The aim should be to incorporate the lime with the first three or four inches of the soil. The tendency for all lime compounds is to sink, to be washed down by the rain, and, therefore, they should never be ploughed under. It is better to make light applications frequently, say once in a rotation if necessary, than large applications at longer intervals. It is well to err on the side of too little than too much, especially if the organic content of the soil cannot be constantly enriched.

GROUND LIMESTONE.—The essential points to be remembered in the purchase of this form are composition and degree of fineness. If a quick, prompt action is desired, a material 75 per cent of which passes through a sieve with 100 meshes to the linear inch, will be found satisfactory. Coarser ground limestones may, however, be successfully used—say 50 to 75 per cent passing through a 50-mesh sieve—and all through a 10-mesh sieve—if immediate and, in a sense quick, decisive action is not important.

The application may be from two to ten tons per acre, according to the character and the acidity of the soil and the degree of fineness of the material. Unlike quick and slaked lime, excess of ground limestone can do little or no harm and the same holds true of marl.

The application of ground limestone and marl offers no special difficulty or unpleasantness; a spreader may be used or the material distributed by a shovel from a wagon. They may be applied at any season of the year and are specially suited, as has been stated, for light loams and soils generally that are poor in organic matter. As with lime they should be harrowed in, not ploughed under, or in the case of meadows or pastures, merely spread on the surface.

INDIRECT FERTILIZERS OR LIBERATORS OF POTASH IN THE SOIL

No other plant food element can replace potash in its important functions, but it has been observed that where marked deficiency of potash occurs in a soil, plants growing thereon will assimilate abnormal quantities of soda.

NITRATE OF SODA, therefore, besides furnishing nitrogen might sometimes fulfil partially the functions of a potassic fertilizer. However, while this fertilizer may directly furnish to some extent soda as a substitute, its value as an indirect source of potash is, undoubtedly, due chiefly to its influence upon the more or less insoluble stores of potash in the soil, from which it may liberate appreciable amounts for crop use.

SODIUM CHLORIDE (common salt).—For the same reason common salt has frequently been used to increase the yields of mangels, potatoes and grain crops.

LIME AND LIME COMPOUNDS.—The function of lime compounds as potash liberators has already been referred to, but this feature is of secondary importance compared with their other useful properties.

GYPSUM, or Land Plaster, as already noted, is a naturally occurring sulphate of lime, of which there are many deposits in Canada. Though possessing no value as a neutralizer of soil acidity, gypsum, when applied judiciously, at the rate of 300 or 400 pounds per acre, may prove beneficial by virtue of its influence in liberating potash from insoluble soil compounds. There have been indications that the sulphur furnished by gypsum may possess a value directly as a plant food to turnips and clover. But there is evidence also that the excessive and long continued use of gypsum will result in impoverishment of the soil's stock of the more important available plant food substances.

CHAPTER IX

FERTILIZER FORMULAE AND HOME-MIXING

THE MEANING OF THE FORMULA

In chapter 7 reference was made to brands of commercial mixed fertilizers, the composition of which is customarily expressed by formulae, such as 2-8-2, 4-8-4, 4-6-10, 5-7-7, etc.

In each case, the figures denote the guaranteed percentages of nitrogen (or ammonia), available phosphoric acid and potash, in that order.

In present trade usage the initial figure expresses nitrogen as ammonia and not as the element nitrogen. By weight 14 parts of nitrogen are equal to 17 parts of ammonia, so 4 per cent of ammonia represents but 3.3 per cent of nitrogen. When the new Dominion Fertilizers Act becomes operative, this method will be changed and thenceforth a 4-8-4 formula will mean that the fertilizer thus designated must contain actually 4 per cent of *nitrogen*, 8 per cent of available phosphoric acid and 4 per cent of potash.

ESTIMATING THE VALUE OF A FERTILIZER FROM ITS ANALYSIS

A fact to be emphasized is that *the commercial value of a mixed fertilizer represents its agricultural value only in so far as its composition conforms to the special requirements of the circumstances.*

A knowledge of the current price per pound or *per unit* of the plant food elements as procurable in the usual forms of nitrate of soda, superphosphate (acid phosphate) and muriate of potash will provide the farmer with a means of estimating the *maximum commercial value* of any fertilizer from its analysis.

The Unit.—In the fertilizer trade prices of nitrogen, phosphoric acid and potash are quoted usually at so much *per unit*. In its application here a unit represents 20 pounds or *one per cent of one ton* (2,000 pounds). The unit thus means a definite amount (always 20 pounds) whether it be a unit of nitrogen, of phosphoric acid, or of potash.

In a ton of a 4-6-8 fertilizer there are 4 units (or 80 pounds) of nitrogen, 6 units (or 120 pounds) of available phosphoric acid and 8 units (or 160 pounds) of potash. The use of the per unit prices simplifies calculations of fertilizer values.

What is the approximate commercial value of a 4-6-8 fertilizer when in the same locality of nitrate of soda may be purchased for \$65, superphosphate for \$28 and muriate of potash for \$60 per ton?

The *per unit price* is obtained simply by dividing the price per ton of the fertilizer material by the percentage of the plant food substance present.

Nitrate of soda contains about $15\frac{1}{2}$ per cent of nitrogen, so we divide \$65 (the price per ton) by 15.5 and obtain \$4.20 as the price per unit of nitrogen.

Superphosphate (ordinary high grade) contains 16 per cent of available phosphoric acid, so \$28 (the price per ton) divided by 16 gives \$1.75 as the price per unit of available phosphoric acid.

Muriate of potash contains 50 per cent of actual potash, so \$60 (the price per ton) divided by 50 gives \$1.20 as the price per unit of potash.

THE PER UNIT PRICES APPLIED IN VALUATIONS

Having obtained the unit prices of nitrogen, phosphoric acid and potash, let us apply them in determining the value per ton of the 4-6-8 fertilizer. And in like manner they may be employed to compute the approximate commercial value per ton of any fertilizer on the market.

	Per cent	Price per unit	Value of Ingredients
Nitrogen.....	4×	\$4.20=	\$16.80 worth of nitrogen.
Phosphoric acid.....	6×	1.75=	10.50 worth of phosphoric acid.
Potash.....	8×	1.20=	9.60 worth of potash.
		Total value.	\$36.90 per ton.

While it is proper to allow a reasonable amount to cover the cost of mixing, it must be remembered that in no commercial mixture do the plant food substances possess a higher value than in those forms used in our illustration.

COMPOUNDING A FERTILIZER ACCORDING TO FORMULA

By reversing the foregoing procedure, we shall see how the equivalent of one ton of our 4-6-8 fertilizer may be prepared from nitrate of soda, superphosphate and muriate of potash.

Multiplying the figure representing the percentage (or number of units) required by 2,000 pounds and dividing the product by the figure representing the percentage present in the component material, gives us the requisite amount of this material Thus:—

Nitrogen	$\frac{4 \times 2,000}{15.5}$	= (about) 520 lbs. of nitrate of soda (15½% Nitrogen)
Phosphoric acid..	$\frac{6 \times 2,000}{16}$	= 750 lbs. of superphosphate (16% Phosphoric Acid)
Potash	$\frac{8 \times 2,000}{50}$	= 320 lbs. of muriate of potash (50% Potash)
		<u>1,590 lbs.</u>

So in 1,590 pounds of our mixture we have the same number of plant food units as are contained in 2,000 pounds of a 4-6-8 brand. Expressed in percentages the plant food substances present in our mixture (of approximately 1,600 pounds) would be represented by the formula, 5-7½-10, instead of 4-6-8 (units).

Thus, while percentages vary with the quality of the components, the unit remains constant, because it represents always a definite quantity.

MIXING FERTILIZERS ON THE FARM

The farmer who is competent to estimate the value of a fertilizer from its statement of analysis, is capable of compounding his own mixtures at home.

The same raw materials used by the manufacturer are available to the farmer in the preparation of his mixtures. The inert "filler" or "make-weight," usually added by the manufacturer, may serve chiefly to reduce the percentages of plant food, thus enabling the product to be marketed at a lower price per ton, though it is used also to keep the mixture in a friable condition, where a long period is likely to elapse between its manufacture and application. From its use for this purpose the filler is known as a "conditioner." The filler may consist of sand, peat, ashes, ground limestone or land plaster. While filler may usually be dispensed with, the admixture with the fertilizers of a small quantity of sandy or loamy soil may facilitate their distribution through the fertilizer drill or other mechanical sower.

The practice of home-mixing generally results in a saving of from 25 to 35 per cent in cost of the materials and possesses the additional advantage of enabling the farmer to prepare his mixtures in such quantities and proportions as circumstances may demand. Moreover, in the employment of the separate materials he knows the source and availability of each plant-food constituent, and may compare their price quotations at various centres.

The operation of home-mixing may be simply and efficiently performed on the barn floor or other firm level floor by means of a square-mouthed shovel, a sand or fanning-mill screen and a mallet or tamper wherewith to break the lumps.

Having assembled the sacks of materials from which the batch is to be prepared, the contents of each sack should be emptied separately on the mixing floor. If the material has set in a hard firm mass the tamper or mallet must be used to reduce the lumps before passing it through the screen, which should have about ten wires to the linear inch.

The lumps which are too coarse to put through the screen may be crushed separately and, when reduced to a sufficient degree of fineness, added to the heap.

Each component of the batch having undergone this preparation, its incorporation with the others may proceed.

The component—usually the phosphatic fertilizer—entering most largely into the mixture ought to be first spread on the floor, the others being superimposed in successive layers. The batch is then turned by shovelling first to one side, then to the other for, say, four or five times. After turning once, the whole batch should be passed through the screen to ensure the absence of lumps and to facilitate mixing.

One ton is usually a sufficient quantity to mix in one batch.

It is, as a rule, desirable to apply the fertilizers to the land at once, or within three days after mixing, in order that hardening or cementing of the materials may be avoided.

Never mix basic slag, wood ashes or other substances containing free caustic lime with sulphate of ammonia, unless for immediate application, as the lime, by displacing the ammonia, causes its escape as gas and a loss in valuable plant food ensues.

METHODS EMPLOYED IN THE APPLICATION OF FERTILIZERS

Where the areas to be fertilized are extensive the application may be performed by means of a broadcast sowing machine or drill. Certain seeding and planting machines are equipped with fertilizer sowing attachment; we prefer, however, the broadcasting method which ensures more uniform distribution.

A method, simple and expeditious, may be found in the use of a two-handed sowing "hopper" or basket. This might be described as a crescent-shaped, canvas-covered frame with waist and shoulder straps attached. Both hands are used in sowing, and to obtain the proper rhythmical motion, it is necessary that the right hand be swung backwards from the hopper as the right foot advances, and vice versa.

The size of the handful and the length of the stride may be regulated according to the rate of application desired.

Where the quantity of fertilizers to be applied is small—as, for instance, in top-dressings of nitrate of soda—in order to ensure uniformity of application, it is desirable to increase the bulk of the fertilizer by mixing it with a quantity of loose dry soil.

TIME OF APPLICATION

The opportune time at which fertilizer applications should be made will be determined to some extent by the nature of the crop, of the climate, and of the fertilizer materials employed.

Speaking generally, most of the phosphatic and potassic fertilizers should be applied during the final cultivation of the land preparatory to seeding.

The nitrogenous fertilizer may be applied at the same time, or when seeding, though some prefer to reserve a portion (assuming it to be in the form of nitrate of soda) for application as a top-dressing later on.

Phosphatic fertilizers, such as basic slag, intended for fall wheat, should be applied in the fall, but soluble nitrogenous fertilizers, like nitrate of soda, should be applied to the wheat in the spring.

Immediately after their application to the thoroughly prepared land, the fertilizers should be incorporated with the surface soil by means of harrows or light cultivator.

In the treatment of pasture and hay lands, the fertilizers should be sown in early spring. Basic slag when used for this purpose should preferably be applied in the fall.

It seems desirable here to emphasize the fact that fertilizers cannot fully play their part in crop nutrition unless the soil is in good tilth. It should be mellow, warm, moist and well aerated, and these favourable conditions will be promoted by furnishing humus-forming material (as in barnyard-manure), drainage, if necessary, and a thorough, frequent working of the surface soil not covered by the crop.

CHAPTER X

FERTILIZER NEEDS OF VARIOUS CROPS

Chief among factors involved in a determination of the composition and quantity of a fertilizer designed to meet the specific requirements of a certain crop, are the nature of (a) the soil, (b) the climatic or seasonal conditions and (c) previous treatment of the land.

THE SOIL.—Clay soils are naturally more plentifully provided with the mineral plant food substances—phosphoric acid and potash—than are sandy soils. Muck soils, consisting essentially of vegetable matter, may often be almost devoid of mineral matter. These, though rich in organic matter and potentially rich in nitrogen, may still derive benefit from applications of farm manure, for the reason that manure contributes to the soil the bacteria which will ultimately, under conditions favourable to their development, promote the decomposition of the muck or peat, liberating therefrom plant food substances. In the fertilizer treatment of muck soils, phosphoric acid and potash, particularly, are important, though nitrogen also, in the form of nitrate may be desirable to encourage early growth.

That the soil characteristics, as viewed externally, may not always be found reliable as a guide to the fertilizer treatment of crops to be grown thereon, is proved by experience recorded in Chapter 3. Of two light sandy soils, one of which is situated in Eastern Canada, the other in Western Canada, one (overlying a gravelly subsoil) has responded in a very marked degree to potassic fertilizers, whereas these applied to the other soil (overlying a silty subsoil) brought forth only a meagre response.

This shows the necessity for discovering the peculiarities of each individual soil in order to practice fertilizer economy.

CLIMATIC OR SEASONAL CONDITIONS.—Degrees of moisture and of temperature are potent factors in determining the size of the crop and, incidentally, the kind and quantity of the fertilizers that may be applied profitably. For example, certain potato growers in New Brunswick find it advantageous to apply a ton of fertilizer to the acre. In Western Ontario the maximum profitable application of a suitably compounded potato fertilizer would possibly be represented by not more than 1,000 pounds per acre.

The cooler, moister climate of New Brunswick is the factor above all which gives that province pre-eminence over Ontario in the production of potatoes per acre. On the other hand, the warmer, drier climate of Western Ontario is more favourable to the production of corn, alfalfa, fall wheat, etc.

PREVIOUS TREATMENT OF THE LAND.—This may be considered chiefly in respect to manuring, fertilizing and cropping.

Speaking generally, when the soil has been enriched by liberal applications of manure the supplemental fertilizer may be smaller in quantity and need not contain such large proportions of nitrogen and potash as would be desirable where no manure has been, or is being, applied.

If for a preceding hoed crop a liberal application of fertilizers has been made, the succeeding grain crop—if it is deemed desirable to stimulate its early growth—may require only a small topdressing of nitrate of soda.

As remarked already, one might do well, in deciding the nature of the fertilizer applications to be given, to consider the draft made on the available plant food substances in the soil by foregoing "exhaustive" crops.

SUGGESTIONS FOR THE FERTILIZER TREATMENT OF VARIOUS FIELD CROPS

In view of the many factors involved, the futility of attempting, with any degree of precision, to prescribe "standard mixtures" for specified crops will be recognized.

Our recommendations, though based on extensive experience in the use of fertilizers and on a knowledge of the characteristics of different crops, their varying abilities to procure the plant food substances and their peculiar appetites, must not be regarded as dogmatic but rather as being in the nature of suggestions.

The limit of profitable application of fertilizers will be determined by the value of the crop, and whether increases in the quantity of fertilizer applied are covered by corresponding increases in crop production.

Thus, of a certain potato fertilizer, 1,500 pounds might be applied profitably in New Brunswick, whereas, in Ontario, any quantity in excess of 750 pounds might produce no increase in crop, or an increase insufficient to repay the cost of the extra quantity of fertilizer used.

The fertilizer prescriptions which follow are to be regarded as approximating normal requirements of the crop as grown, say, on a medium loam soil and treated otherwise in accordance with ordinary farm practice.

For the sake of uniformity and for purposes of comparison, the more usual sources (of constant high grade composition) of the plant food substances will be given in the formulæ or prescriptions. Variations in this respect will be indicated in supplemental examples.

In the tabulated prescriptions the weight of each fertilizer component as well as the number of pounds of each constituent (nitrogen, phosphoric acid or potash) furnished, *per acre*, will be shown. Furthermore, assuming the addition of a certain quantity of inert "filler" to the mixture, and making it thus more on a parity with those found in commerce, the analysis (expressed in the usual formula) of the mixture, assumed to be diluted by the filler, is stated in the following manner: "650 lbs. (actual) equal to 800 lbs. (assumed) of 4-6-8 goods."

FERTILIZER APPLICATIONS (PER ACRE) PRESCRIBED FOR VARIOUS CROPS

No. 1 For Grain Crops (when seeded down with grasses or clover).

	Pounds per acre		
	Nitrogen (N)	Phosphoric Acid (P ₂ O ₅)	Potash (K ₂ O)
Nitrate of soda..... 100 lbs.....	15½	24	25
Superphosphate.... 150 ".....			
Muriate of potash.. 50 ".....			
300 lbs., equal to 400 lbs. 4-6-6 goods.			

Basic slag (300 lbs. per acre) may profitably replace the superphosphate, especially where clover has been seeded.

Fall wheat, or other grain not seeded down with clover or grass seed, may require only *nitrate of soda* (100-150 lbs. per acre) to encourage vigorous, early growth in the spring.

No. 2 For Potatoes

	N	P ₂ O ₅	K ₂ O
Nitrate of soda..... 260 lbs.....	40	48	75
Superphosphate.... 300 ".....			
Muriate of potash.. 150 ".....			
710 lbs., equal to 800 lbs. of 5-6-9 goods.			

While, in general, *nitrate of soda* has proved superior to *sulphate of ammonia* as a source of nitrogen in the potato fertilizer, results of certain experiments have indicated that a mixture of the two may sometimes yield results superior to those from the use of either alone. Mixture No. 2a shows the nitrogen to be derived equally from both sources.

No. 2a.

For Potatoes

		N	P ₂ O ₅	K ₂ O
Nitrate of soda.....	130 lbs.....	20		
Sulphate of ammonia	100 ".....	20		
Superphosphate.....	300 ".....		48	
Muriate of potash....	150 ".....			75
680 lbs., equal to 800 lbs. of 5-6-9 goods.		40	48	75

No. 3.

For Turnips

		N	P ₂ O ₅	K ₂ O
Nitrate of soda.....	150 lbs.....	23		
Superphosphate.....	450 ".....		72	
Muriate of potash....	50 ".....			25
650 lbs., equal to 800 lbs. of 3-9-3 goods.				

Basic slag may sometimes be substituted, with distinct advantage, for *superphosphate* in the turnip fertilizer, especially where the crop is liable to an attack of "*club-root*."

No. 4.

For Mangels and Beets

		N	P ₂ O ₅	K ₂ O
Nitrate of soda.....	200 lbs.....	31		
Superphosphate.....	300 ".....		48	
Muriate of potash....	100 ".....			50
600 lbs., equal to 800 lbs. of 4-6-6 goods.				

It will be noted that No. 1 corresponds in composition to No. 4, the difference being in quantity only.

No. 5.

For Corn

		N	P ₂ O ₅	K ₂ O
Nitrate of soda.....	120 lbs.....	18		
Superphosphate.....	300 ".....		48	
Muriate of potash....	100 ".....			50
520 lbs., equal to 600 lbs. of 3-8-8 goods.				

No. 6.

For Timothy Hay

		N	P ₂ O ₅	K ₂ O
Nitrate of soda.....	150 lbs.....	23		
Superphosphate.....	200 ".....		32	
Muriate of potash....	50 ".....			25
400 lbs. equal to 600 lbs. of 4-5-4 goods.				

On timothy hay *nitrate of soda* applied alone, at the rate of 200 lbs. per acre, may be found quite as efficient as the mixture.

No. 7.

For Clover and Alfalfa

	N	P ₂ O ₅	K ₂ O
Nitrate of soda..... 100 lbs.....	15		
Superphosphate..... 300 ".....		48	
Muriate of potash.... 100 ".....			50
500 lbs., equal to 700 lbs. of 2-7-7 goods.			

For clover *basic slag* (500 lbs. per acre) may, with profit, be substituted for *superphosphate*.

No. 8.

For Flax

	N	P ₂ O ₅	K ₂ O
Nitrate of soda..... 160 lbs.....	25		
Superphosphate..... 190 ".....		30	
Muriate of potash.... 100 ".....			50
450 lbs., equal to 600 lbs. of 4-5-8 goods.			

No. 9.

For Tobacco

	N	P ₂ O ₅	K ₂ O
Sulphate of ammonia. 175 lbs.....	35		
Superphosphate..... 250 ".....		42	
Sulphate of potash.... 140 ".....			70
575 lbs., equal to 700 lbs. of 5-6-10 goods.			

No. 10.

For Tomatoes

	N	P ₂ O ₅	K ₂ O
Nitrate of soda..... 200 lbs.....	31		
Superphosphate..... 400 ".....		64	
Muriate of potash.... 100 ".....			50
700 lbs., equal to 800 lbs. of 4-8-6 goods.			

No. 11.

For Cabbage and other Leafy Vegetables

	N	P ₂ O ₅	K ₂ O
Nitrate of soda..... 380 lbs.....	59		
Superphosphate..... 320 ".....		51	
Muriate of potash.... 200 ".....			100
900 lbs., equal to 1,000 lbs. of 6-5-10 goods.			

For Small Fruits

	N	P ₂ O ₅	K ₂ O
Nitrate of soda..... 200 lbs.....	31		
Superphosphate..... 300 ".....		48	
Muriate of potash.... 130 ".....			65
630 lbs. equal to 800 lbs. of 4-6-8 goods.			

FOR APPLE ORCHARDS

Unlike field crops, which have an annual habit of growth and must develop their root, stem, branch and, sometimes, fruit all in a single season, the apple tree has a permanently established root system, trunk and superstructure. Its widely ramifying roots penetrate to a considerable depth and are ready to draw nutriment from an extensive soil area, as these are rendered available for absorption.

As a result of lengthy and extensive research, nearly all investigators of the subject agree that, except on soils of the lighter types, or on sod, applications of phosphatic and potassic fertilizers are seldom profitable in the apple orchard. Fruit spur growth and fruit production are influenced, however, in marked degree by the supply of nitrate nitrogen. This is furnished by nitrate of soda applied, at the rate of 5 to 10 pounds per tree (or 200 to 400 pounds per acre), about three weeks before blossoming time. This practice is becoming general in the orchards of the Annapolis Valley in Nova Scotia.

MIXTURES CONTAINING ORGANIC MATERIALS

Among potato growers and market gardeners, who apply customarily very large quantities of fertilizers, are some who consider it desirable to include organic materials, such as tankage or bone meal, in the mixture. The organic materials in such mixtures are regarded by some chiefly as "conditioners," by others rather as a means of furnishing nitrogen and phosphoric acid during the later period of growth.

The New Brunswick potato grower who compounds his own fertilizer mixtures, if he uses tankage at all, considers 200 pounds per ton a sufficient quantity of this organic material to incorporate with the mixture.

By introducing 200 pounds of tankage (containing 8 per cent nitrogen and 8 per cent phosphoric acid) per ton our 5-6-9 mixture (No. 2) would be modified as follows:—

For Potatoes

One ton Mixture (with tankage)

	Pounds per ton		
	N	P ₂ O ₅	K ₂ O
Nitrate of soda..... 540 lbs.....	84		
Tankage..... 200 ".....	16	16	
Superphosphate..... 650 ".....		104	
Muriate of potash.... 360 ".....			180
1,750 lbs., equal to 2,000 lbs. of 5-6-9 goods.	100	120	180

While a ton per acre of this mixture might be applied with profit on certain potato fields in New Brunswick, the same quantity would serve adequately from two to three acres of potatoes in Ontario.

There are market gardeners who, being unable to procure suitable manure conveniently, show a preference for fertilizers containing relatively large quantities of organic materials.

We will show here a mixture (corresponding to No. 11) containing both tankage (8 per cent N, 8 per cent P_2O_5) and bone meal (3 per cent N, 15 per cent available P_2O_5).

For Market Gardens

One ton Mixture (with Tankage and Bone)

		Pounds per ton		
		N	P_2O_5	K ₂ O
Nitrate of soda.....	460 lbs.....	71		
Tankage.....	500 ".....	40	40	
Bone meal.....	300 ".....	9	45	
Superphosphate.....	100 ".....		16	
Muriate of potash.....	400 ".....			200
1,760 lbs., equal to 2,000 lbs. of 6-5-10 goods.		120	101	200

A mixture like the foregoing may prove quite suitable when applied in large quantities for market garden purposes, though, because of the small proportion of readily available phosphoric acid present, will prove less suitable in small applications.

Our experience in the use of organic sources of nitrogen and phosphoric acid in fertilizers—part of which has been recorded in Chapter 4—coincides with that of other investigators in Europe and the United States, and leads us to favour, for ordinary field crops, those fertilizers which furnish the essential plant food substances largely in readily available forms.

CAL/BCA OTTAWA K1A 0C5



3 9073 00215723 0

